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CLEAN AIR ENGINEERING-MARITIME, INC.

UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

WESTERN DIVISION

CLEAN AIR ENGINEERING-MARITIME, INC., a California corporation, Plaintiff and Counter-defendant, v. ADVANCED CLEANUP TECHNOLOGIES, INC., and ADVANCED ENVIRONMENTAL GROUP, LLC [sic], a California corporation, Defendants and Counter-claimants.	Case No. 2:12-cv-08669-JAK-VBK **DIRECT TESTIMONY DECLARATION OF MARKO PRINCEVAC, PH.D.** Date: November 18, 2014 Time: 8:30 a.m. Place: Roybal 750 – 7th Floor Judge: John A. Kronstadt

DECLARATION OF MARKO PRINCEVAC, PH.D.

I, Marko Princevac, Ph.D., declare as follows:

I. QUALIFICATION AS AN EXPERT WITNESS

1. This Declaration is made in lieu of direct testimony at trial, as directed by the Court. I am an expert witness in the case, and all of the statements set forth below are based upon personal knowledge and/or belief.

Current Employment, Education and Publications

2. I am an Associate Professor in Mechanical Engineering at the Bourns College of Engineering at the University of California, Riverside.

3. I received a B.Sc. degree in Mechanical Engineering and Naval Architecture from the University of Belgrade in Serbia in 1997 and a Ph.D. in Mechanical Engineering from Arizona State University in 2003.

4. After one year of postdoctoral research after receiving my Ph.D., I began teaching at UC Riverside in 2004 and have been teaching there for the last ten years, gaining tenure in 2010.

5. My *curriculum vitae* and publications list are attached as Exhibit 1.

Experience In General

6. I have studied and worked extensively in the fields of air pollution, environmental engineering, naval architecture, and mechanical engineering for the past seventeen years. I have extensive knowledge of diesel and internal combustion engines, their emissions, and control of those emissions, from cars, boats, and other sources.

7. The focus of my research has been in fundamental and applied fluid mechanics—in particular, the application of fundamental turbulence concepts to studies in environmental flows. In this area, I identify physical phenomena and build physical (laboratory) models that can successfully explain complex field observations or a part thereof. I also have experience developing idealized theoretical models to explain fluid dynamic processes. My approach has been to

cross-fertilize field measurements with carefully designed laboratory experiments and simple theoretical analysis.

8. My early research focused on "engineering flows," specifically ships' propulsion and resistance. This research resulted in several polynomial models for the estimation of the power and resistance for the specific type of semi-displacement hull forms. In graduate school I focused my research on thermally driven environmental flows, motivated by tremendous air quality problems that are occurring in cities located in areas with complex terrain.

9. I currently focus on field experimental research on urban flows, specifically on urban dispersion (pollutants or toxic releases, industrial disasters or terrorist attacks) and parameterizations of turbulence within urban canyons.

10. I teach classes dealing with air pollution. The class Environmental Impacts of Energy Production & Conversion (ME136) is part of the Energy and Environment focus area within the Department of Mechanical Engineering. This class covers thermodynamics, heat transfer, and fluid mechanics as applied to the examination of the environmental impacts of energy production and conversion. Topics include pollution associated with fossil fuel combustion, environmental impacts of energy use, turbulent transport of pollutants, and principles used in the design of pollution control equipment. Many of my recent projects and field experiments involve air pollution and the study of emissions and how they travel and disperse in the atmosphere. I recently completed a project that modeled transportation emissions from cars, and I have worked on other projects involving distributed generation sources that involve the study of emissions from internal combustion engines and generators.

Experience in Marine Engineering

11. I am also involved in marine engineering. As an undergraduate, I majored in naval architecture, where I learned about boat building, including managing boat exhaust. I currently own a sailboat with a diesel engine, which I sail

several times a month on average. I recently completed a project involving the impact of hydrogen injection in marine diesel engines for the California Air Resources Board (CARB). This project resulted in an article I published in the *International Journal of Hydrogen Energy* titled, "Effect of Hydrogen Addition on Criteria and Greenhouse Gas Emissions for Marine Diesel Engine."

12. I have tested tugboat emissions in the Port of Los Angeles. This testing involved hybrid (diesel-electric) internal combustion engines for the tugboats. I am on the doctoral qualifying committee for two doctoral candidates who are using this data for their Ph.D. work.

Memberships

13. I am a member of The Society of Naval Architects and Marine Engineers (SNAME), The American Meteorological Society (AMS), and The American Society of Mechanical Engineers (ASME).

14. Based on this background, I am tendered as a qualified expert witness in the field of diesel and internal combustion engines, their emissions, and control of those emissions, from cars, boats, and other sources.

II. PRIOR TESTIMONY AND OPINIONS

15. I have submitted two prior written opinions and have been deposed in this case.

16. First, I submitted an Expert Report dated April 2, 2014 where I opined that Claim 19 of the U.S. Patent No. 7,258,710 (the "'710 Patent") (Exhibit 2) was invalid as anticipated by U.S. Patent No. 6,185,934 ("Teboul")(Exhibit 3)("Expert Report"). A true and correct copy of that Expert Report is attached as Exhibit 4 to this Declaration and incorporated herein by reference.

17. Second, I submitted a Declaration Of Marko Princevac Ph.D. In Support of Plaintiff Clean Air Engineering-Maritime, Inc.'s Motion For Summary Judgment dated May 20, 2014 ("MSJ Declaration"). A true and correct copy of that MSJ Declaration is attached as Exhibit 5 to this Declaration and incorporated

herein by reference.

18. Third, I was deposed by Defendants on May 16, 2014 where I provided testimony relating to this case.

19. My testimony and opinions in the Expert Report, my deposition and the MSJ Declaration have remained unchanged and I still believe those prior facts and opinions to be true and accurate to the best of my knowledge.

III. ORDER ON MOTION FOR SUMMARY JUDGMENT

20. I have reviewed the Order Granting In Part and Denying In Part Plaintiff's Motion For Summary Judgment entered in this case on July 28, 2014 as Docket No. 120 ("MSJ Order"). I have primarily focused my review on the portion of the MSJ Order relating to the "Validity of '710 Patent Claim 19" beginning on page 13 and ending on page 19.

21. From this portion of the MSJ Order, I understand that the Court has found all the claim elements of claim 19 in Teboul with the exception of the claim 19 element "Ocean Going Vessel (OGV)." With regard to OGV, I understand that the Court has unanswered questions "concerning the nature of the genus-species relationship between a boat [of Teboul] and an Ocean Going Vessel [of claim 19]." MSJ Order at 19.

22. I further understand that these factual questions specifically relate to "how one of ordinary skill in the art would understand the relative size of a genus or species…between Teboul's 'boat' and the claim's 'Ocean Going Vessel….'" MSJ Order at 18.

23. And lastly, I understand the MSJ Order asks that these factual questions address both invalidity under 35 U.S.C. § 102 (anticipation) and 35 U.S.C. § 103 (obviousness). I will now provide my testimony and opinions on these remaining factual questions.

IV. TEBOUL'S "BOAT" ANTICIPATES CLAIM 19'S "OGV"

24. Prior to the MSJ Order, I provided testimony in my Expert Report, my

MSJ Declaration and during my deposition opining that Teboul's "boat" anticipates the "Ocean Going Vessel" ("OGV") of claim 19 of the '710 Patent. Expert Report at 11 ("Thus, Teboul discloses that its apparatus may be used with a boat, a ship, or other ocean going vessel."); MSJ Declaration at 11 ("Thus, Teboul discloses that its apparatus may be used with a boat, a ship, or other ocean going vessel."); May 16, 2014 Deposition of Marko Princevac, Ph.D. at 39-43. As I mentioned above, those opinions and testimony have not changed. However, the MSJ Order asks for more testimony on understanding of the boat/OGV relationship by a person of ordinary skill in the art.

25. I now understand from the MSJ Order that (i) the "boat" of Teboul is considered a "genus;" (ii) the "OGV" of claim 19 is considered a "species" of that "genus;" and (iii) this genus/species relationship has significance under patent law. Specifically, I am told that, under patent law, "whether a generic disclosure necessarily anticipates everything within the genus … depends on the factual aspects of the specific disclosure and the particular products at issue." *Sanofi-Syntheiabo v. Opotex*, 550 F.3d 1075, 1083 (Fed Cir. 2008).

26. In this case, I understand that whether the genus "boat" anticipates the species "OGV" depends on the disclosure in Teboul and whether one of ordinary skill in the art, at the time of the filing of the '710 Patent (April 29, 2004), would "at once envisage" the "OGV" of claim 19 given the "boat" disclosure in Teboul.

27. For the reasons explained below, it is my testimony, as a person of ordinary skill in the art, that I would have envisioned the OGV of claim 19 in 2004 given the "boat" disclosure in Teboul.

28. Also for the reasons explained below, it is my opinion, as an expert in this case, that a person of ordinary skill in the art would have envisioned the OGV of claim 19 in 2004 given the "boat" disclosure in Teboul.

29. I first provide the law as explained to me by lawyers for the Plaintiff and then I provide the underlying reasons for my testimony and opinion.

A. Law Relied Upon

30. As I stated above, I am an expert in the field of diesel and internal combustion engines, their emissions, and control of those emissions, from cars, boats, and other sources. I am not a lawyer and therefore I have relied on the relevant law as explained to me by lawyers for the Plaintiff for my opinions on invalidity. While my Expert Report and MSJ Declaration, incorporated by reference, detail the relevant law I am relying on, I restate that law here for ease of reference.

Burden Of Proof

31. On the burden of proof, attorneys for CAEMI[1] have informed me of a number of legal principles regarding patent validity that I have taken into account in forming my opinions. As an initial matter, it is my understanding that patent applications are reviewed and approved by examiners trained in the technical field of the invention. Because of this examination process, an issued patent is presumed to be valid over the prior art. Accordingly, there is a burden on a party challenging the validity of a patent – that party must prove that a patent is invalid by clear and convincing evidence. I further understand that this means that the party challenging the validity of a patent must demonstrate an abiding conviction that the truth of the factual contentions is highly probable.

32. Because of the presumption of validity of United States patents, I understand the burden of proving invalidity of the '710 Patent is on CAEMI.

Person of Ordinary Skill In The Art

33. Based on my years as a professor of graduate and undergraduate students, and as an advisor to Master's and Ph.D. candidates in Mechanical Engineering, I believe that the definition of a person of ordinary skill in the art relating to the '710 Patent is one who would have at least a B.S. degree in mechanical or environmental engineering, or an equivalent formal education, and

[1] Plaintiff Clean Air Engineering-Maritime, Inc. ("CAEMI").

would have at least two years of work or research experience involving diesel emissions or related areas. One of ordinary skill in the art could also have a Master's degree in one of these same fields and at least one year of relevant work or research experience.

Anticipation

34. For invalidity, it has been explained to me that a claim may be invalidated by "anticipation."

35. It has further been explained to me that under the doctrine of anticipation in effect when the '710 Patent issued (under 35 U.S.C. § 102), a claim may be anticipated if it is not new – that is, if there is a single prior art reference that discloses, explicitly or inherently, all of the limitations of the patent claim.

Genus/Species

36. It has also been explained to me that "species are unpatentable when prior art disclosures describe the genus containing those species such that a person of ordinary skill in the art would be able to envision every member of the class."[2] *Abbvie Inc. v. Mathilda & Terence Kennedy Inst. of Rheumatology Trust*, 764 F.3d 1366, 1379 (Fed. Cir. 2014).

37. It has also been explained to me that "[w]here the claimed advance over the prior art lies in focusing on the special attributes of a sub-genus that is part of a genus already broadly disclosed, there is ***particular need*** to show that the limitation is critical." *Cal. Research Corp. v. Ladd*, 356 F.2d 813, 820 (D.C. Cir.

[2] It has also been explained to me that prior recitations of the genus anticipation standard have referenced the relative size of the genus. *See, e.g., Wm. Wrigley Jr. Co. v. Cadbury Adams USA LLC*, 683 F.3d 1356, 1361 (Fed. Cir. 2012) ("issue of anticipation turns on whether the genus was of such a defined and limited class that one of ordinary skill in the art could 'at once envisage' each member of the genus"). But I understand that the courts recently "clarified that the outcome of [a] case need not rest heavily on the size of the genus disclosed by a prior art reference," so long as "one of ordinary skill in the art would have favorably considered the species patent at issue." *Abbvie*, 764 F.3d at 1379 (internal brackets omitted).

1966) (emphasis added). "The criticality issue turns on whether the claim is an advance over products and processes previously known and sufficiently distinctive to warrant a patent monopoly." *Id.* "There must be a distinctive physical … discovery. A mere location of optimum conditions and characteristics, however useful, is said not to warrant a patent monopoly." *Id.*

<u>Changing Size</u>

38. It has also been explained to me that "mere size is not ordinarily a matter of invention." *In re Yount*, 171 F.2d 317, 318 (C.C.P.A. 1948). More directly, the "mere scaling up of a prior art process capable of being scaled up … [does] not establish patentability." *In re Rinehart*, 531 F.2d 1048, 1053 (C.C.P.A. 1976); *see also Bristol-Myers Squibb Co. v. Teva Pharm. USA, Inc.*, 752 F.3d 967, 977 (Fed. Cir. 2014) ("While a 'marked superiority' in an expected property may be enough in some circumstances to render a compound patentable, a 'mere difference in degree' is insufficient"); *Murray Co. of Tex. v. Cont'l Gin Co.*, 264 F.2d 65, 70 (5th Cir. 1959) ("mere enlargement is not invention").

B. Reasons A Person Of Ordinary Skill In The Art Would Have Envisioned The OGV Of Claim 19 In 2004 Given The "Boat" Disclosure In Teboul

39. To explain why a person of ordinary skill in the art would have envisioned the "OGV" of claim 19 in 2004 given the "boat" disclosure in Teboul, I will first explain the scope and content of the disclosure in Teboul to one of ordinary skill in the art. Next, I will compare that disclosure to the "OGV" of claim 19 to ascertain the differences between an "OGV" and "boat" to one of ordinary skill in the art. Lastly, I will explain why a person of ordinary skill in the art would have envisioned the "OGV" of claim 19 in 2004 given the "boat" disclosure in Teboul based on these differences.

<u>Scope and Content Of "Boat" Disclosure in Teboul</u>

40. Teboul unambiguously discloses an emissions control system that can

be used to process exhaust produced by a "boat." Teboul, Column 5, lines 15-19.

41. Teboul also discloses that the emissions control system can be used on a car or "any motor vehicle whatsoever…" (Teboul, Column 5, lines 17-18) and is "adaptable to any motor vehicle." Teboul, Column 1, lines 62-63.

42. To a person of ordinary skill in the art reading these portions of Teboul in 2004, the disclosure of Teboul would disclose that the filtering device of Teboul can be used broadly on any motor vehicle and more specifically on a "boat."

<u>Differences Between "OGV" And "Boat" To One of Ordinary Skill In The Art</u>

43. Claim 19 does not use the word "boat" but instead uses "OGV" in the claim language of "securing a bonnet over a stack of an Ocean Going Vessel (OGV) to capture exhaust." '710 Patent, claim 19.

44. To a person of ordinary skill in the art in 2004, the difference between a "boat" and an "OGV" is whether the vessel (used generically to refer to a boat including an OGV) is designed (constructed) to be used in open ocean water (termed "seaworthy"). Thus, the primary difference is the "strength" of the construction of the vessel in determining whether it is a "boat" (which may or may not have strong construction and therefore may or may not be seaworthy) or an "OGV" (strong construction and therefore seaworthy). I will explain this understanding and then give examples.

45. This explanation is based on my experience as a person of ordinary skill in the art. Independently, it is also based on my understanding as a qualified expert who knows what a person of ordinary skill in the art in 2004 would understand in this art.

46. Vessels (again, used generically to refer to a boat including an OGV) are constructed using (i) specific building materials (for example, wood, fiberglass and steel); (ii) properly dimensioned structural elements; and (iii) manufacturing procedures (such as welding). The "strength" of those building materials, structural

elements and procedures used for construction is based on the intended use of the vessel. For example, if the vessel is a pontoon vessel used for small social "cruises" in water near land that will never leave a harbor or never navigate more than a few miles from the coastline, then the "strength" of the building materials (thickness of the steel, type of wood, etc.) need not be as "strong" as a vessel intended to go into open ocean waters ("seaworthy"). On the other hand, if the vessel is designed to go out in the open ocean water, miles from land, with high winds and high waves, the "strength" of construction for this vessel must be stronger to withstand the rough seas. In other words, it must be "seaworthy."

47. Importantly, it is this intended purpose of the vessel that determines whether it should have a stronger construction to enable it to be used in rough seas. It is not the size, weight or propulsion mechanism of a vessel that qualifies a vessel to go out into the open ocean. For example, there are many small and light vessels that are seaworthy based on the strength of the structural elements used in their construction. My sailboat, for example, is a 37 foot vessel that is certified to be taken out in open ocean water and is seaworthy.

48. The American Bureau of Shipping ("ABS") is the leading U.S. ship classification society that promulgates rules and guidelines for materials, structural elements, welding regulations and other ship building procedures. In the U.S., certification by ABS is used to classify vessels and manufacturers based on the strength of the construction and a vessel's ability to withstand rough sea in open ocean water.

49. Regarding propulsion mechanisms, such mechanisms are not used to classify vessels as OGVs. Almost all vessels now have some type of engine or motor (even most sailboats). A person of ordinary skill in the art in 2004 would never distinguish between "boat" and "OGV" based on the type of propulsion mechanism used.

50. Likewise, the amount of pollution generated by a vessel does not affect

the classification of a vessel as either a boat or an OGV. For example, many vessels burn different types of fuels when in harbor than in open seas, so the amount or type of pollutants does not change the classification of the vessel as it moves away from harbors.

51. In summary, a person of ordinary skill in the art understood in 2004 that the only feature distinguishing "OGV" from other "boats" was whether the vessel was designed (constructed) to go into open ocean water (seaworthy).

<u>A Person Of Ordinary Skill In The Art Would Have Envisioned The "OGV" Of Claim 19 In 2004 Given The "Boat" Disclosure In Teboul Based On These Differences</u>

52. As explained, a person of ordinary skill in the art understood in 2004 that the only feature distinguishing an "OGV" from other "boats" was the strength of the construction and manufacturing procedures used to design and construct the vessel.

53. That same person of ordinary skill in the art, viewing the disclosure of "boat" in Teboul in 2004, would understand that Teboul disclosed that the filtering device was intended to be used on "any motor vehicle whatsoever" including a "boat." There is nothing in Teboul that limited use of the filtering device to vessels that are not seaworthy. In fact, the manner in which Teboul explains that the filtering device can be used with "any motor vehicle" would lead a person of ordinary skill in the art to understand that the filtering device could be used on either a strong vessel (boat that is an OGV) or a less strong vessel (boat that is not an OGV).

54. In addition, a person of ordinary skill in the art in 2004 would generally use the word "boat" to refer to both vessels that are seaworthy and those that are not seaworthy. In general, those skilled in the art who wanted to note a difference between a seaworthy vessel and a non-seaworthy vessel would refer to the latter as a "boat that is not seaworthy." Otherwise, a word "boat" generally is

used to refer to both a seaworthy and non-seaworthy vessel.

55. As one skilled in the art, "ocean going vessel" was generally used in 2004 to refer to a vessel that is strongly built for rough seas, regardless of the size, weight, propulsion mechanism or amount of pollution generated.

56. Lastly, I note that both Teboul and the '710 Patent disclose that those inventions can be used on vessels of different size. Teboul cites to U.S. Patent No. 4,338,784 (Exhibit 6) on its cover page under "References Cited" and that patent's specification states that "it is understood that the changes in the structure, including the particle collector, power supply, materials, and **sizes of the parts** can be made by those skilled in the art without departing from the invention." Column 17, lines 57-61 (emphasis added).

57. Likewise, the '710 Patent specification specifically discloses that the emission control invention need not be used **only** on an OGV, but also for "control of emissions from land based equipment" (*i.e.*, not an OGV). '710 Patent, Column 7, lines 8-11. A person of ordinary skill in the art reading this portion of the '710 Patent would understand that it is not critical that an OGV be used.

58. Also, U.S. Patent Number 5,980,343 ("343 Patent") (Exhibit 7) is cited on the face of the '710 Patent and discloses an exhaust system for marine vessels such as yachts and smaller boats. '343 Patent, Column 1, lines 13-14. It discloses that "[f]or different vessels and/or different engines, the **size** of the mufflers, number of seawater discharge openings and size of the skeg assemblies **can be appropriately scaled up or down**. Such reasonable variations and modifications are possible within the spirit of the foregoing specification and drawings without departing from the scope of the invention." '343 Patent, Column 6, lines 29-34 (emphasis added). Thus, one of ordinary skill in the art viewing the OGV of the '710 Patent and this disclosure in the '343 Patent would understand that the size of the OGV is not critical.

59. In summary, a person of ordinary skill in the art in 2004 viewing

Teboul's "boat" would have envisioned the "OGV" of claim 19 since (1) "boat" was understood to one of ordinary skill in the art to refer to both seaworthy and non-seaworthy vessels; (2) Teboul makes no distinction to sea worthiness in the disclosure and in fact discloses "any motor vehicles" meaning to one of ordinary skill in the art that the filtering device of Teboul can apply to both seaworthy and non-seaworthy vessels; (3) size, weight, propulsion mechanism and amount of pollution are irrelevant to the determination of whether a "boat" is an "OGV"; and (4) Teboul and the '710 Patent both disclose that the size of the physical components of the inventions may be adjusted as needed and therefore the size of the vessel is not critical.

60. For these reasons, it is my opinion that the "boat" of Teboul anticipates the "OGV" of claim 19 and therefore claim 19 is invalid given that the Court has found all other elements of claim 19 in Teboul in the MSJ Order.

V. TEBOUL'S "BOAT" RENDERS OBVIOUS CLAIM 19'S "OGV"

61. The MSJ Order states that whether claim 19 "is invalid as obvious under 35 U.S.C. § 103…may also be addressed efficiently through the same trial process." MSJ Order at 1.

62. As with anticipation, I understand that the Court has found all the claim elements of claim 19 in Teboul with the exception of the claim 19 element "Ocean Going Vessel (OGV)."

63. I will therefore provide my testimony and opinions on whether Teboul's "boat" renders claim 19's "OGV" obvious by providing the law of obviousness explained to me and then my testimony and opinions based on the understandings of a person of ordinary skill in the art.

A. Law Relied Upon

64. I relied upon the same law with regard to burden of proof and person of ordinary skill provided above.

65. For obviousness, it has been explained to me that even if a prior art

reference does not anticipate a claim under 35 U.S.C. § 102, it can still render the claim obvious under § 103. *See* 35 U.S.C. § 103 ("notwithstanding that the claimed invention is not identically disclosed as set forth in section 102 …"). "Obviousness is a question of law based on underlying factual findings," including "(1) the scope and content of the prior art; (2) the differences between the claims and the prior art; (3) the level of ordinary skill in the art." [3] *OSRAM Sylvania, Inc. v. Am. Induction Techs, Inc.*, 701 F.3d 698, 706 (Fed. Cir. 2012)(citing *Graham v. John Deere Co.*, 383 U.S. 1, 17-18 (1966)); *accord KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 399 (2007). But "overall [the] obviousness inquiry must be expansive and flexible." *OSRAM Sylvania*, 701 F.3d at 707. Ultimately, "to invalidate a patent as obvious," a court must find "that a skilled artisan would have been motivated to combine the teaching of the prior art references to achieve the claimed invention, and that the skilled artisan would have had a reasonable expectation of success in doing so.'" *Id.* at 706.

66. A teaching, suggestion, or motivation to combine references is no longer required under *KSR Int'l, Inc. v. Teleflex Inc.*, 550 U.S. 398 (2007). Rather, the "combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results." *Id.* at 401. "When a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field" or a different one. *Id.* "For the same reason, if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill." *Id.* at 417.

67. In order to determine whether there is an apparent reason to combine

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[3] Establishing the first three *Graham* factors established a *prima facie* case of obviousness, which the patentee may attempt to rebut with proof of secondary considerations such as the commercial success of the patent. *KSR*, 550 U.S. at 399.

the known elements in the fashion claimed by the patent at issue, a court can "look to interrelated teachings of multiple patents; to the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art . . . ." *Id*. at 418. For example, obviousness can be demonstrated "by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims." *Id*. at 420. "[A]ny need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed." *Id*. "Common sense [also] teaches . . . that familiar items may have obvious uses beyond their primary purposes, and in many cases a person of ordinary skill will be able to fit the teachings of multiple patents together like pieces of a puzzle." *Id*.

68. The motivation to combine the teachings of the prior art references disclosed discussed in this Declaration below is found in the references themselves and/or: (1) the nature of the problem being solved, (2) the express, implied and inherent teachings of the prior art, (3) the knowledge of persons of ordinary skill in the art, (4) the fact that the prior art is directed towards related art, and/or (5) the predictable results obtained in combining the different elements of the prior art.

B. Reasons An "OGV" Of Claim 19 Would Have Been Obvious To One of Ordinary Skill In The Art In 2004 Given The "Boat" Disclosure In Teboul

69. I understand that, to show obviousness, facts are needed related to the following factors: "(1) the scope and content of the prior art; (2) the differences between the claims and the prior art; and (3) the level of ordinary skill in the art." *OSRAM Sylvania*, 701 F.3d at 706 (citing *Graham v. John Deere Co.*, 383 U.S. 1, 17-18 (1966)); *accord KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 399 (2007).

70. I provided facts related to all three factors above under the anticipation analysis and incorporate all those factual findings here with regard to obviousness

given that those facts are identical to those needed under the obviousness determination.

71. To reiterate, to a person of ordinary skill in the art in 2004, the distinguishing feature between an "OGV" and other "boats" is whether the vessel (used generically to refer to a boat, including an OGV) is designed (constructed) to be "seaworthy." Thus, the primary difference is the "strength" of the construction of the vessel in determining whether it is a "boat" (not strong construction and therefore not seaworthy) or an "OGV" (strong construction and therefore seaworthy).

72. As a person of ordinary skill in the art in 2004, these differences between Teboul and the '710 Patent invention as a whole would have been obvious. This is because a person of ordinary skill in the art in 2004 would generally use the word "boat" to refer to both vessels that are seaworthy and those that are not seaworthy. In general, those skilled in the art who wanted to note a difference between a seaworthy vessel and a non-seaworthy vessel would refer to the latter as a "boat that is not seaworthy." Otherwise, the word "boat" generally is used to refer to both a seaworthy and non-seaworthy vessel. The Teboul reference alone would render the OGV of claim 19 obvious since a person of ordinary skill in the art at that time would consider "boat" to include an "OGV" for this reason.

73. In addition, there were additional patents available in 2004 that, when combined with Teboul, would expressly disclose that a "boat" would be understood to disclose an" OGV" to one of ordinary skill in the art.

74. U.S. Patent No. 3,835,625 (Exhibit 8), in combination with Teboul and the knowledge of one of ordinary skill in the art, would render claim 19's "OGV" obvious over Teboul's "boat." For example, the '625 Patent is entitled "POLLUTION-REDUCING FLOATING EXHAUST," and deals with controlling emissions from a watercraft. The motivation to combine the teachings of Teboul and the '625 Patent are found in the fact that both references relate to reduction of

pollutants on water vessels.

75. U.S. Patent No. 5,632,660 (Exhibit 9), in combination with Teboul and the knowledge of one of ordinary skill in the art, would render claim 19's "OGV" obvious over Teboul's "boat." For example, the '660 Patent teaches "[a] number of embodiments of personal watercraft having catalytic exhaust systems for treating and purifying the exhaust gases." (Abstract). The motivation to combine the teachings of Teboul and the '660 Patent are found in the fact that both references relate to reduction of pollutants on water vessels.

76. U.S. Patent No. 5,967,063 (Exhibit 10), in combination with Teboul and the knowledge of one of ordinary skill in the art, would render claim 19's "OGV" obvious over Teboul's "boat." For example, the '063 Patent discloses a system for "remov[ing] some hazardous smoke particles" from smoke emanating from a chimney on a "sea-going vessel" (Abstract) The motivation to combine the teachings of Teboul and the '063 Patent are found in the fact that both references relate to reduction of pollutants on sea-going vessels.

77. U.S. Patent No. 6,395,047 (Exhibit 11), in combination with Teboul and the knowledge of one of ordinary skill in the art, would render claim 19's "OGV" obvious over Teboul's "boat." For example, the '047 Patent teaches an "airborne contamination control" system that filters particles from air. (Abstract) The motivation to combine the teachings of Teboul and the '063 Patent are found in the fact that both references relate to reduction of pollutants in motor vehicles.

78. U.S. Patent No. 6,983,757 (Exhibit 12), in combination with Teboul and the knowledge of one of ordinary skill in the art, would render claim 19's "OGV" obvious over Teboul's "boat." For example, the '757 Patent discloses a system that can be used to capture material emitted from "motor vehicle exhaust systems." Column 1, lines 24-32. The motivation to combine the teachings of Teboul and the '063 Patent are found in the fact that both references relate to reduction of pollutants on motor vehicles.

79. In summary, the Teboul reference alone would render the OGV of claim 19 obvious since a person of ordinary skill in the art at that time would consider "boat" to include an "OGV" for the reasons above. In addition, the Teboul reference in combination with any one of U.S. Patent Nos. 3,835,625; 5,632,660; 5,967,063; 6,395,047 or 6,983,757 (along with the knowledge of a person skilled in the art) would render the OGV of claim 19 obvious.

80. For these reasons, it is my opinion that the "boat" of Teboul renders obvious the "OGV" of claim 19 and therefore claim 19 is invalid given that the Court has found all other elements of claim 19 in Teboul in the MSJ Order.

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I declare under penalty of perjury that the foregoing is true and correct.

Executed this 17th day of October, 2014 at Riverside, California.

Marko Princevac

Marko Princevac, Ph.D.

Exhibit 1

Curriculum Vitae

Marko Princevac

Department of Mechanical Engineering, Bourns College of Engineering, University of California, Riverside, CA 92521, Phone: (951) 827-2445, Fax: (951) 827-2899, marko@engr.ucr.edu

Education

2003: Ph.D. in Mechanical Engineering, Arizona State University, U.S.A.
1997: B.Sc. in Mechanical Engineering and Naval Architecture, University of Belgrade, Serbia.

Awards

2009: European Meteorological Society, Kipp & Zonen Award for Boundary Layer Meteorology
2007: UC Regents' Fellowship
2005: UC Regents' Faculty Development Award
2003: Arizona State University recognition for an exemplary job of serving students
2003: Air & Waste Management Association scholarship
1999: "Graduate Assistantship in Area of National Need" scholarship, US Department of Education
1997: Best student in department
1995: JAT fellowship as IAESTE nominee
1992: Best student of generation
1986-1992: Several times winning national and regional competitions organized by the National Association of Young Scientists and Engineers

Work Experience in Academia

2010-present: Associate Professor. University of California, Riverside, Bourns College of Engineering, Department of Mechanical Engineering

2004-2010: Assistant Professor. University of California, Riverside, Bourns College of Engineering, Department of Mechanical Engineering

2003-2004: Post Doctoral Research Associate. Arizona State University, Mechanical and Aerospace Engineering.

1999-2003: Research Assistant, Arizona State University.
Research consisted of laboratory experiments, field measurements and theoretical analysis, with the main goal being better understanding of nature and structure of thermally driven flows in complex terrain.

2000: Teaching Assistant, Arizona State University.
Served as a Teaching Assistant for two undergraduate courses (under the auspices of the GAANN program).

1997-1999: Assistant Lecturer and Research Assistant, University of Belgrade.
Served as an Assistant Lecturer for three upper level undergraduate courses and doing research on ship resistance and propulsion of semi-displacement hull forms.

Industrial Work Experience

2013-: "Solar Turbines", San Diego, CA, U.S.A. Swirling cooling of the first turbine stage – in charge of a test cell.

2012-2013: "World Kitchen"/"Snapware", Mira Loma, CA. Consulting on fire polishing.

1995: "Premez Clados Del Norte", Matamoros, Tamaulipas, Mexico. Working as a laboratory and field supervisor.

1994: "Roller-Bearing Industry Belgrade", Serbia. Working on problems of final polishing of the inner and outer bearing rings.

Professional Affiliations

The American Society of Mechanical Engineers (ASME)
The American Meteorological Society (AMS)
The Society of Naval Architects and Marine Engineers (SNAME)

Projects

Measurements of thermal load on fire engines, FS SDTDC, PI, 2013.

Chaparral Fire – Passive or Active Crown Fire, PSW FS, PI, 2013-2014.

Cooling of the first turbine stage, Solar Turbines, PI, 2013-2016.

Ecosystem Ozone (O3) Flux and Stomatal Uptake: Assessment of Environmental Controls and Functional Responses of Mixed Conifer Sites Along Two Pollution Gradients. USDA PSW, Co-PI, 2012-2013.

Systematical physical modeling of sound walls, three-lines, sunken and raised roadways. SCAQMD, PI, 2011-2012.

Model for Air Quality forecast for Santiago, Chile. Mario Molina Center, Santiago, Chile, 2011-2012.

Measurements of thermal load on bulldozers, FS SDTDC, PI, 2010.

Impact of hydrogen injection in marine diesel engine, CARB, PI, 2010.

Improving understanding of regional and near-source air quality impacts of DG sources, CEC, Co-PI, 2009-2013.

Superfog formation: laboratory experiments and model development, USDA JFSP, PI, 2009-2012.

Success Partnership for Increasing Recruitment into Technology (SPIRIT), NSF, Co-PI, 2008-2009.

Near Source Modeling of Transportation Emiss. in Built Environ. Surrounding Major Arterials, UCTC, PI, 2007-2009.

Investigation of Fluxes along Urban/Rural Transect, UC Regents, PI, 2007-2008.

Near Field Impact of Distributed Generation through Tracer Studies and Water Channel Testing, CEC, Co-PI, 2007-2009.

New Tools for Estimating and managing Local/Regional Air Quality Impacts of Prescribed Burns, SERDP, Co-PI, 2008-2010.

Exploratory field study on the relationships between meteorology and air quality, EPA, Co-PI, 2006-2007.

Flume experiments: high resolution velocity measurements around multi-building arrays, LANL, PI, 2006-2007.

Laboratory Investigation of Flow and Dispersion through Urban Canopies, UC Regents, PI, 2005-2006.

Environmental Monitoring and Highway Noise, ADOT, Co-PI, 2004-2005.

Air Flow and Dispersion Over an Urban Downtown Area, ARO, Co-PI, 2003-2006.

Field Experiments

2013 – Dozer Burn Study, part 2. Sponsored by San Dimas Technology Development Center.
2013 – Ozone Flux measurements, UCR Orchard, Sponsored by FS.
2012 – 2013 – Sap flux measurements, James Reserve, Sponsored by FS.
2011: Fire Truck Burn Study, Ione, CA, Sponsored by SERDP.
2011: Nocturnal Urban Boundary Layer Development, Riverside, CA. Sponsored by CEC.
2010: Dozer Burn Study. Sponsored by Forest Service San Dimas Technology Development Center.
2010: Plume rise study – Palm Springs, CA. Sponsored by CEC.
2009-
2010: Emissions from prescribed burns. Sponsored by DoD SERDP.
2008: Transportation Emissions in Built Environments Surrounding Major Arterials in Los Angeles, Long Beach, Huntington Beach, Anaheim and Pasadena. Sponsored by UC Transportation Center
2008: Dispersion Study of distributed power generators in Lancaster, CA and Palm Springs, CA sponsored by the California Energy Commission
2007: Prescribed Burn measurements at Three Hills, Murrieta, CA.
2007: Urban-rural fluxes, Riverside-Moreno Valley, CA
2006: Riverside Energy Balance Experiment. Pune, India - International USEPA air quality program.

2005: Wilmington Dispersion Study. California Air Resources Board sponsored program

2004: Environmental monitoring of the highway noise. Arizona Department of Transportation sponsored program.

2003: Joint Urban 2003 Experiment, Oklahoma City. US Department of Defense, Army Research Office and Defense Treat Reduction Agency sponsored program. Deployment of meteorological towers and operation of the CTI's Doppler LIDAR.

2002: Douglas Aerosol Experiment. Southwest Center for Environmental Research and Policy sponsored program. Organization of the experiment, coordinating team members, setting up of the instrumentation, data gathering and data managing.

2001: Mock Urban Settings Test Experiment. US Department of Defense sponsored program. Organization of ASU team and equipment, setting up of the instrumentation, data gathering and data managing.

2001: Phoenix Ozone Experiment. US Department of Energy sponsored program. Supervising ASU team (5-6 people). Took care of experiment organization and preparation, setting up of the instrumentation, data gathering and data managing.

2000: Vertical Transport and Mixing Experiment. US Department of Energy sponsored program. In charge of instrument preparation, field planning, data gathering, data managing and exchange of data with DOE.

2000: Wall Study field experiment. US Department of Education sponsored through the GAANN program. In charge of vertical profiling.

Graduated Doctoral and Master Students

Maynard, Trevor, Ph.D. Dissertation: *Fire Interactions and Pulsation – Theoretical and Physical Modeling*, 2013. Currently at San Dimas Technology Development Center, San Dimas, CA.

Pournazeri, Sam, Ph.D. Dissertation: *Plume Rise and Dispersion of Emissions from Low Level Buoyant Sources in Urban Areas*, 2012. Currently at the California Air Resources Board, Sacramento, CA.

Pan, Hansheng, Ph.D. Dissertation: *Investigation of Flow, Turbulence, and Dispersion within Built Environments*, 2011. Currently Research Associate at Southern Methodist University, Dallas, TX.

Li, Xiangyi, Ph.D. Dissertation: *Flow, Turbulence, and Dispersion Above and Within the Roughness Sublayer: Field Observations and Laboratory Modeling*, 2009. Currently at the California Air Resources Board, Enforcement Division, Heavy-Duty Diesel Enforcement Section, El Monte, CA.

Gazzolo, Brandn, M.Sc. Thesis: *Near Field Modeling of the Effects of Sound Barriers on Flow and Dispersion*, 2012. Currently at the Naval Surface Warfare Center in Corona, CA.

Zhang, Yanyan, M.Sc. Thesis: *Model of Flow through Urban-Like Obstacle Arrays and Energy Balance Parameterization*, 2009. Currently at CGG Veritas, Houston, TX.

Chen, Shiyan, M.Sc. Thesis: *Laboratory and Field Investigation of Buoyant Plume Structure and Ground Level Concentration*, 2009. Currently at the California Air Resources Board, El Monte, CA.

Cole, Taylor, M.Sc. Thesis: *Water Channel Design and Street Canyon Flow Modeling*, 2007. Currently at the Naval Surface Warfare Center in Corona, CA.

Diagne, PapaMagatte, M.Sc. Thesis: *Field Investigation of the Environmental Energy Balance*, 2006. Currently at the Simpson Gumpertz & Heger Inc. in Los Angeles, CA.

Student Awards

Trevor Maynard: PERISHIP fellowship in disasters and hazards research (2011), AMS best oral presentation (2010, 2012)

Sam Pournazeri: AMS Best Technical Content Paper (2012)

Hansheng Pan: Academic Excellence Award by Women's Resource Center (2010)

Xianguy Li: Outstanding Graduate Student Volunteer UCR (2007), Best Oral Presentation at 2nd UCR M.E. Graduate Research Symposium (2007), Dissertation Research Grant (2006), College Graduate Fellowship (2006)

Teaching

Undergraduate Courses

- Introduction to Mechanical Engineering (ME2)
- Introduction Fluid Mechanics (ME113)
- Energy and Environment (ME136)
- Environmental Fluid Mechanics (ME137)
- Experimental Techniques (ME170B)

Graduate Courses

- Fundamentals of Fluid Mechanics (ME240A)
- Fundamentals of Fluid Mechanics (ME240B)
- Turbulence in Fluids (ME242)
- Apprentice Teaching (ME302)

Service

Department

- Undergraduate Advisor, 2010 -2013
- ABET accreditation coordinator, 2007-present
- Undergraduate committee, 2004-2013
- Freshman mentor, 2005-2009
- Seminar coordinator, 2006-2007
- ASME Faculty Advisor, 2007-2008
- Graduate Advisor, 2013-present

University

- Research Integrated Safety Committee (RISC), 2005-present
- RISC vice-Chair, 2007-present
- Faculty Panel Participant for Enginuity Hall, 2008, 2009
- Senate's Committee on Courses, 2009-2012
- Senate's Committee on Undergraduate Admissions, 2013-present

Public

- College representative of the ASME California Inland section, 2005- present
- Member of the American Meteorological Society Committee on Meteorological Aspects of Air Pollution (AMS CMAAP), 2008-present
- Chair of the AMS CMAAP, 2010-present
- Organizer of 17th and 18th AMS Conference on Air Pollution
- Reviewer for several journals and funding agencies
- Chair and co-Chair at several national and international meetings
- Guest Editor of the special issue of Environmental Fluid Mechanics, 2012-2014.
- Judge and moderator at local science fairs and undergraduate conferences

Conference Organizations

17th Air Pollution Conference, as a part of 92nd AMS Annual Meeting, New Orleans, LA, 2012.

Symposium on Transport and Dispersion from Fukushima Dai Chi Nuclear Power Plant, as a part of 93rd AMS Annual Meeting, Austin, TX, 2013.

18th Air Pollution Conference, as a part of 94nd AMS Annual Meeting, Atlanta, GA, 2014.

Symposium on Advances in Fluid Mechanics and Turbulence: Analysis and Applications, as a part of annual AAAS meeting, Riverside, CA, 2014.

Selected Invited Talks

- Lecture at the Stellar Hydrology Days titled "*Laboratory and Field Measurements of Environmental Stratified Flows*", July 2006.
- Graduate seminar at the Seoul National University titled "*Multi-scale Flow and Transport Processes in Urban Environments*", October 2007.

- Graduate seminar at UC San Diego titled "*Flow pattern through a simple urban array - water channel experiments and modeling*", November 2007.
- Lectures at the workshop organized by US EPA and NEERI in Mumbai, India: Emission Inventory for Air Quality Management, titled *Micrometeorological Measurements* and *Selected Field Measurement Results*, December 2007.
- Graduate seminar at UC Irvine titled "*Field Measurements and Water Channel Modeling of Flow and Dispersion within Simple Arrays and in Southern Californian Cities*", April 2009.
- Lecture at the Korean Institute for Science and Technology (KIST) titled "*Field Measurements and Laboratory Modeling of Environmental Flows from Meso-scale to Street-scale*", June 2009.
- Invited presentation at the "Favela as Urban Experience Workshop" in Rio de Janeiro, Brazil, titled "Multi-scale Flows, Transport Processes and Pollution Sources in Urban Environments", September 2011.
- Graduate seminar at UC San Diego titled "*Scaling of Building Affected Plume Rise and Dispersion in Water Channels and Wind Tunnels - Revisit of an Old Problem*", February 2012.
- Riverside STEM Academy, *A few words about fluids: boating, pollution, fire, birds…,* December 2012
- Invited lecture to the Naval Warfare College, SSG, *Understanding Forces in Fluids*, Newport, RI, November 2013.

Journal Articles

36. Pournazeri S., Schulte N., Tan S., Princevac M., Venkatram A., Dispersion of buoyant emissions from low level sources in urban areas: water channel modelling, *Int. J. Environment and Pollution*, Vol. 52, Nos. 3/4, 2013.

35. Pan, H., C. Bartolome, E. Gutierrez, M. Princevac, R. Edwards, M.G. Boarnet, D. Houston, Investigation of Roadside Fine Particulate Matter Concentration Surrounding Major Arterials in Five Southern Californian Cities, *Journal of Air and Waste Management Association*, Vol. 63: 4 p.482-498.

34. Pournazeri, S., Gazzolo, B., Princevac, M., Development of an Air Dispersion Model to Study Near-Road Exposure. Environmental Management. July 2013.

33. Pournazeri, S., M. Princevac, A. Venkatram, Rise of Buoyant Emissions from Low-Level Sources in the Presence of Upstream and Downstream Obstacles, *Boundary Layer Meteorology*, 144, 287-308, 2012.

32. Pournazeri, S., P. Segre, M. Princevac, D. Altshuler, Hummingbirds generate bilateral vortex loops during hovering: evidence from flow visualization, *Experiments in Fluids,* 54:1439, 2012.

31. Pournazeri, S., Venkatram, A., Princevac, M., Tan, S.. Schulte, N., Estimating the height of the nocturnal urban boundary layer for dispersion applications, *Atmospheric Environment*, 54, 611-623, 2012.

30. Bartolome, C., H. Gonzalez, M. Princevac, A. Venkatram, D.R. Weise, G. Achtemeier, G. Aguilar, S. Mahalingam, Numerical and Physical Investigation of the Properties of Superfog, Bulletin of the American Meteorological Society, 93(6), 780-781, 2012

29. Maynard, T. and M. Princevac, The application of a simple free convection model to the pool fire pulsation problem, *Combustion Science and Technology*, 184(4), 505-516, 2012.

28. Pournazeri, S., M. Princevac, and A. Venkatram, Scaling of Urban Plume Rise and Dispersion in Water Channels and Wind Tunnels - Revisit of an Old Problem, *Journal of Wind Engineering and Industrial Aerodynamics*, 103, 16-30, 2012.

27. Boarnet, M., D. Houston, R. Edwards, M. Princevac, G. Ferguson, H. Pan, C. Bartolome, Fine particulate concentrations on sidewalks in five Southern California cities, *Atmospheric Environment*, 45, 4025-4033, 2011.

26. Princevac, M., J. Bühler, A. Schleiss, Alternative depth-averaged models for gravity currents and free shear flows, *Environmental Fluid Mechanics*, 10, 369-386, 2010.

25. Princevac, M., J.-J. Baik, X. Li, S.-B. Park and H. Pan, Lateral channeling within rectangular arrays of cubical obstacles, *Journal of Wind Engineering and Industrial Aerodynamic*, 98, 377-385, 2010.

24. Hosseini S., Q. Li, D. Cocker, D. Weise, A. Miller, M. Shrivastava, J. W. Miller, S. Mahalingam, M. Princevac, and H. Jung, *Particle size distributions from laboratory-scale biomass fires using fast response instruments*, Atmos. Chem. Phys., 10, 8065-8076, 2010.

23. Zajic D., H.J.S. Fernando, R. Calhoun, M. Princevac, M.J. Brown, E.R. Pardyjak, “Flow and Turbulence in an Urban Canyon”, *Journal of Applied Meteorology*, 50, 1, 203-223, 2011.

22. Lozano J., W. Tachajapong, D. Weise, S. Mahalingam, M. Princevac, Fluid Dynamic Structures in a Fire Environment Observed in Laboratory Scale Experiments, April, *Combustion Science and Technology*, 35, 2009.

21. Qian W., M. Princevac, A. Venkatram, 'Using Temperature Fluctuation Measurements to Estimate Meteorological Inputs for Modeling Dispersion during Convective Conditions in Urban Areas, *Boundary Layer Meteorology*, 135, 269-289, 2010.

20. Noroozi Z., H. Kido, M. Micic, H. Pan, C. Bartolome, M. Princevac, J. Zoval, and M. Madou: Reciprocating flow-based centrifugal microfluidic mixer, *Review of Scientific Instruments*, 80, 075102, 2009.

19. Altshuler D., M. Princevac, H. Pan, and J. Lozano, 'Wake patterns of the wings and tail of hovering hummingbirds, *Experiments in Fluids,* 46, 835-846, 2009.

18. Princevac, M, J. Buhler and A. Schleiss: Mass-based depth and velocity scales for gravity currents and related flows, *Environmental Fluid Mechanics*, 9, 369-387, 2009.

17. Lee, S., M. Princevac, S. Mitsutomi, and J. Cassmassi: MM5 Simulations for Air Quality Modeling: An Application to a Coastal Area with Complex Terrain, *Atmospheric Environment*, 43, 447-457, 2009.

16. Li X., N. Zimmerman, M. Princevac: Local Imbalance of Turbulent Kinetic Energy in the Surface Layer, *Boundary-Layer Meteorology*, 129:115–136, 2008.

15. Venkatram, A. and M. Princevac, Using measurements in urban areas to estimate turbulent velocities for modeling dispersion, *Atmos. Environ.*, 42(16), 3833-3841, 2008.

14. Princevac, M. and H.J.S. Fernando: Morning breakup of cold pools in complex terrain, *Journal of Fluid Mechanics*, 616, 99–109, 2008.

13. Princevac, M., J.C.R. Hunt, and H.J.S. Fernando, “Quasi-Steady Katabatic Winds on Long Slopes and In Wide Valleys: Hydraulic Theory and Observations”, *Journal of the Atmospheric Sciences*, 65, 627-643, 2008.

12. Princevac, M. and A. Venkatram, “Estimating Micrometeorological Inputs for Modeling Dispersion in Urban Areas during Stable Conditions“, *Atmospheric Environment*, 41(26), 5345-5356, 2007.

11. Princevac, M. and H.J.S. Fernando, “A Criterion for the Generation of Anabatic Flow”, *Physics of Fluids*, 19(10), 105102, 2007.

10. Calhoun R, Heap R, Princevac M, Newsom R, Fernando H, and Ligon D: Virtual towers using coherent Doppler lidar during the Joint Urban 2003 dispersion experiment, *Journal Of Applied Meteorology And Climatology* 45(8): 1116-1126, 2006.

9. Lee, S.M., W. Giori, M. Princevac, and H.J.S. Fernando, “'Implementation of a Stable PBL Turbulence Parameterization for the Mesoscale Model MM5: Nocturnal Flow in Complex Terrain”, *Boundary Layer Meteo.*, 119(1): 109-134. APR 2006.

8. Newsom R.K., D. Ligon, R. Calhoun, R. Heap, E. Cregan, and M. Princevac, “Retrieval of Microscale Wind and Temperature Fields from Single- and Dual-Doppler Lidar Data”, *Journal of Applied Meteorology*, 44(9), pages 1324-1345, 2005.

7. Princevac, M., H.J.S. Fernando, and C.D. Whiteman, “Turbulent entrainment into natural gravity-driven flows”, *Journal of Fluid Mechanics*, 533, 259-268, 2005.

6. Fernando H.J.S. and M. Princevac, “'Internal tides and the continental slope”, *American Scientist*, 92(5), 397, 2004.

5. Hunt, J.C.R., H.J.S. Fernando, and M. Princevac, “Unsteady Thermally Driven Flows on Gentle Slopes”, *Journal of the Atmospheric Sciences*, Vol. 60, No. 17, pp. 2169–2182, 2003.

4. Lee, S.M., H.J.S. Fernando, M. Princevac, M. Sinesi, D. Zajic, and J. Anderson, "Transport and Diffusion of Ozone in the Nocturnal and Morning PBL of the Phoenix Valley", *Environmental Fluid Dynamics*, Vol 3 (4), 331-362, 2003.

3. Monti, P., H.J.S. Fernando, M. Princevac, W.C. Chan, T.A. Kowalewski and E. R. Pardyjak, "Observations of Flow and Turbulence in the Nocturnal Boundary Layer Over a Slope", *Journal of the Atmospheric Sciences*, Vol 59 (17), 2513-2534, 2002.

2. Fernando, H.J.S., S.M. Lee, J. Anderson, M. Princevac, E. Pardyjak , and S. Grossman-Clarke, "Urban Fluid Mechanics: Air Circulation and Contaminant Dispersion in Cities", *Environmental Fluid Dynamics*, Vol 1, 107-164, 2000.

1. Radojcic, D., M. Princevac and T. Rodic, "Resistance and Trim Predictions for the SKLAD Semidisplacement Hull Series", *Oceanic Engineering International*, Vol. 3 (1), 34-50, 1999

Journal Articles - Submitted

Pan, H., M. Princevac, W. Miller, S. Mahalingam, M. Khan, V. Jayaram, W. Welch, Effect of Hydrogen Injection on Emissions from a Two-Stroke Marine Diesel Engine, August, *Fuel*, 15, 2011.

Pournazeri, S, M. Princevac, A. Venkatram, Dispersion of Buoyant Emissions from Low Level Sources in Urban Areas: Water Channel Modelling, *International Journal of Environment and Pollution*, 33, 2013.

Maynard, T., M. Princevac, D.R. Weise, A study of the flow field surrounding interacting line fires, *International Journal of Wildfire*, 36, 2013.

Journal Articles in Preparation

Princevac, M, Y. Zhang, and P. Diagne: Improved Model for Estimation of Sensible and Latent Heat. to be submitted to the *Environmental Fluid Mechanics*.

Princevac, M., X. Li, and H. Pan: Influence of Tall Buildings on Street Level Flow Pattern, to be submitted to the *Journal of Wind Engineering and Urban Aerodynamics*.

Princevac, M., P. Monti, and H.J.S. Fernando, "Wave contribution to momentum and buoyancy transport in nocturnal, stably stratified, flows", to be submitted to *Physics of Fluids*

Bartolome C., M. Princevac, A. Venkatram, S. Mahalingam, D. Weise, G. Achtemeier, H. Vu, G. Aguilar, Superfog: Laboratory Measurements and Sensitivity Modeling, *Agriculture and Forest Meteorology*, 23.

Book chapters

"Springer Handbook of Experimental Fluid Mechanics", Eds. Tropea, Yarin, and Foss, Springer, Chapter 17.1, 1557pp, 2007.

"Animal Locomotion", Eds. Taylor, Graham; Triantafyllou, Michael S.; Tropea, Cameron, Springer, 350pp, 2010

Conferences (proceedings and abstracts)

126. D. Weise, W, Miller, D. Cocker, H. Jung, S. Hosseini, M. Princevac, R. Yokelson, I. Burling, S. Akagi, S. Urbanski, W. Hao, Recent emissions research in southwestern shrub and grassland fuels, Proceedings of the International Smoke Symposium, Published by the International Association of Wildland Fire, Missoula, Montana, USA, October 21-24, 2013, Hyattsville, Maryland, USA.

125. C. Bartolome, Princevac, M., Weise, D., Venkatram, A., Achtemeier, G., Development of a New Superfog Screening Tool through Theoretical, Experimental and Numerical Investigation . International Smoke Symposium 2013. Adelphi, MD. October 2013.

124. D. Weise, Miller, W., Yokelson, R., Urbanski, S., Cocker, D., Jung, H., Princevac, M., Burling, I., Akagi, S., Hosseini, E. . Measuring Smoke Emissions on DOD Installations: 1. Southwestern Shrub and Grassland Fuels. 94th Annual AMS meeting. Atlanta, GA. February 2014.

123. H. Kondo, Iwasaki, T., Yamada, T., Princevac, M., A Summary of Fukushima Special Symposium at the AMS 2013 Annual Meeting and Scientific Communication Efforts with the Public in Japan. 94th Annual AMS Meeting. Atlanta, GA. February 2014.

122. S. Pournazeri, Gazzolo, B., Princevac, M., Sound Walls and Air Quality Mitigation. Atlanta, GA. February 2014.

121. C. Bartolome, Princevac, M., Weise, D., Venkatram, A., Achtemeier, G. . Development of a New Superfog Screening Tool through Theoretical, Experimental and Numerical Investigation. 94th Annual AMS Meeting. Atlanta, GA. February 2014.

120. K. Alstad, Bartolome, C., Princevac, M., Bytnerowicz, A., Comparison of two high frequency ozone instruments for eddy-covariance flux of an urban orchard: UV versus . 94 Annual AMS Meeting. Atlanta, GA. February 2013.

119. H. Pan, M. Princevac, A. Venkatram, S. Lee, C. Bartolome, R. Edwards "Investigation of the Variation in Meteorological Variables and Fine Particulate Concentrations At Street Level in Urban Areas" AMS 92nd Annual Meeting, 1, New Orleans, LA, January 2012

118. C. Bartolome, M. Princevac, A. Venkatram, S. Mahalingam, G. Achtemeier, D. Weise, H. Vu, G. Aguilar "Numerical and Physical Investigation of the Properties of Superfog" AMS 92nd Annual Meeting, 1, New Orleans, LA, January 2012

117. V. Lu, K. Tsui, C. Bartolome, M. Princevac, A. Venkatram, S. Mahalingam, G. Achtemeier, D. Weise "Laboratory Measurements and Characterization of Smoldering Smoke From Pine Needle Fuel Beds" AMS 92nd Annual Meeting, 1, New Orleans, LA, January 2012

116. S. Pournazeri, M. Princevac, A. Venkatram "A New Method on Scaling the Urban Plume Rise and Dispersion in Water Channels" AMS 92nd Annual Meeting, 1, New Orleans, LA, January 2012

115. B. Gazzolo, S. Pournazeri, M. Princevac "The Assessment of Sound Barriers on near Roadway Air Quality" AMS 92nd Annual Meeting, 1, New Orleans, LA, January 2012

114. Z. Wang, C. Chien, G. Tonnesen, W. Miller, M. Princevac, H. Gonzalez, R. Moore "Meteorological and Air Quality Modeling of a 2009 Prescribe Burn Event" AMS Ninth Symposium on Fire and Forest Meteorology, 1, Palm Springs, CA, October 2011.

113. S. Pournazeri, Q. Jing, M. Princevac, A. Venkatram, "Investigating Dispersion of Buoyant Emissions from Low level Sources in Urban Areas: Water Channel Modeling," *Annual Meeting of the American Meteorological Society*, Seattle, WA, January 2011, 7, 2011.

112. C. Bartolome, M. Princevac, A. Venkatram, S. Mahalingam, D. Weise, G. Achtemeier, H. Vu, G. Aguilar, "Laboratory Measurements and Sensitivity Modeling of Droplet Characteristics and Implications for Superfog," *ILASS-Americas 23rd Annual Conference on Liquid Atomization and Spray Systems*, Ventura, CA, May 2011, 10, 2011.

111. P. Monti, H. Fernando, M. Princevac, "On Quantifying Waves and Turbulence Contributions in Katabatic Flows," May, *Seventh International Symposium on Stratified Flows*, Roma, Italy, August 2011, 5, 2011

110. M. Boarnet, R. Edwards, G. Ferguson, M. Princevac, J. Wu, R. Lejano, "Planning To Reduce Fine Particulate Exposure Near Arterial Streets," February, *Association of Collegiate Schools of Planning Annual Conference*, Crystal City, Virginia, October 2009, 1, 2009.

109. D. Weise, W. Miller, D. Cocker, H. Jung, R. Yokelson, W. Hao, S. Urbanski, M. Princevac, S. Mahalingam, I. Burling, "*Development of new fuels and emissions data for maritime chaparral and Madrean oak woodland fuel types*", 3rd Fire Behavior and Fuels Conference, October 25-29, 2010, Spokane, Washington, USA.

108. M. Princevac, S. Pournazeri, A. Venkatram, *"Fiber Optic Assisted LIF Measurements in a Water Channel"*, 15th Int. Symp on Applications of Laser Techniques to Fluid Mechanics, Lisbon, Portugal, 05-08 July, 2010.

107. J. Bühler, M. Princevac, A.J. Schleiss, "*Entrainment by katabatic winds*", 6th International Symposium on Environmental Hydraulics (ISEH), 23-25 June, Athens, Greece, 2010.

106. A.Venkatram, S. Pournazeri, M. Princevac, D. Pankratz and Q. Jing, *"Dispersion of Buoyant Emissions from Low Level Sources in Urban Areas"*, 31st NATO/SPS International Technical Meeting (ITM) on Air Pollution Modelling and its Application, 27 Sept - 01 Oct, Torino, Italy, 2010.

105. S. Hosseini, Q. Li, A. Miller, M. Sharivastava, D. Cocker, W. Miller, S. Mahalingam1, M. Princevac, D. Weise, M.T. Odman, J. Reardon, T. Johnson, H. Jung, "*Particle size distribution from a controlled biomass burning in the laboratory using fast response particle instruments"* WSSCI Spring 2010 Meeting, Boulder, March 21-23, 2010.

104. W. Qian, M. Princevac, A. Venkatram *"Estimating urban dispersion meteorology from suburban measurements"* 90th AMS Annual Meeting, 16th Conference on Air Pollution Meteorology, 1, Atlanta, GA., January 2010.

103. Q. Jing, A. Venkatram, M. Princevac, D. Pankratz *"Modeling Dispersion of Buoyant Emissions from a Low Level Source in an Urban Area"* 90th AMS Annual Meeting, 16th Conference on Air Pollution Meteorology, 1, Atlanta, GA, January 2010.

102. H. Pan, C. Bartolome, M. Princevac, R. Edwards *"Influence of urban morphology on street level concentration: Water channel and field study in three Southern Californian Cities"* 90th AMS Annual Meeting, 16th Conference on Air Pollution Meteorology, 1, Atlanta, GA, January 2010.

101. S. Pournazeri, H. Pan, E. Pellereau, M. Princevac *"Localized effect of building height on street level flows and concentration: water channel modeling"* 90th AMS Annual Meeting, 16th Conference on Air Pollution Meteorology, 1, Atlanta, GA, January 2010.

100. C. Bartolome, S. Chen, X. Li, M. Princevac, A. Venkatram, D. Pankratz *"Field and laboratory plume dispersion studies of buoyant plume release in an urban environment"* 90th AMS Annual Meeting, 16th Conference on Air Pollution Meteorology, 1, Atlanta, GA, January 2010.

99. T. Maynard, S. Hosseini, M. Princevac, S. Mahalingam, H. Jung, D. Cocker, W. Miller, D. Weise, W. Hao, R. Yokelson *"Laboratory-based experimental measurement of particulate emission factors for wildland fuels"* 90th AMS Annual Meeting, 16th Conference on Air Pollution Meteorology, 1, Atlanta, GA, January 2010.

98. M. Princevac, S. Pournazeri, A. Venkatram *"Fiber Optic Assisted LIF Measurements in a Water Channel"* 15th Int. Symp on Appl. Laser Techniques to Fluid Mechanics, 12, Lisbon, Portugal, July 2010.

97. A. Asa-Awuku, C. Bartolome, D. Cocker, S. Hosseini, H. Jung, J. Lozano, S. Mahalingam, T. Maynard, W. Miller, M. Princevac, L. Qi, M. Sharivastava, D. Switzer, B. Yokelson, I. Burling, S. Akagi, J. Roberts, P. Veres, A. Miller, D. Weise, W. Hao, S. Urbanski "New Tools for Estimating and Managing Local/Regional Air Quality Impacts of Prescribed Burns" Partners in Environmental Technology Technical Symposium and Workshop, Washington, D.C., December 2009.

96. C. Bartolome, H. Pan, M. Princevac, R. Edwards, A. Sfazl, M. Boarnet, J. Wu, R. Lejano *"Field measurements and numerical modeling of vehicular PM2.5 emissions in Los Angles and Huntington Beach with QUIC Model"* 2009 UCTC conference, 1 page, Riverside, CA, February 2009.

95. H. Pan, M. Princevac, R. Edwards, A. Sfazl, M. Boarnet, J. Wu, R. Lejano *"The influence of urban morphometry on flow and dispersion of vehicular PM2.5 emissions in Southern Californian cities: field, laboratory and numerical study"* 2009 UCTC conference, 1 page, Riverside, CA, February 2009.

94. H. Pan, M. Princevac, C. Bartolome, R. Edwards, A. Sfazl, M. Boarnet, J. Wu, R. Lejano *"Field, laboratory and numerical study of flow and dispersion of vehicular PM2.5 emissions in major arterials in Southern Californian cities"* 3rd Southern California Symposium on Flow Physics, 1 page, San Diego, CA, April 2009

93. C. Bartolome, H. Pan, M. Princevac, R. Edwards, A. Sfazl, M. Boarnet, J. Wu, R. Lejano *"Laboratory, Field, and Numerical Modeling of Vehicular Emissions in Los Angles and Huntington Beach"* Symposium for Undergraduate Research, Scholarship and Creative Activity, 1 page, Riverside, CA, May 2009

92. T. Maynard, M. Princevac, S. Mahalingam, J. Lozano *"Laboratory study of particulate emissions factors of prescribed wildland fires"* 3rd Southern California Symposium on Flow Physics, 1 page, San Diego, CA, April 2009

91. M. Michel, C. Bartolome, S. Chen, X. Li, M. Princevac *"Distributed Power Generator Dispersion Simulation in a Water Channel"* Symposium for Undergraduate Research, Scholarship and Creative Activity, 1 page, Riverside, CA, May 2009

90. A. Fata, M. Michel, C. Bartolome, M. Princevac "Laboratory Modeling & Parameterization of Superfog

Generation" SCCUR 2009, 1, California State University Dominguez Hills, November 2009

89. S. Pournazeri, M. Princevac, A. Venkatram *"Laboratory Measurements of flow and dispersion of pollutants released from near ground sources in urban areas"* SoCal Symposium of Fluid Mechanics, Irvine, CA, April 2010

88.G. Knight, S. Pournazeri, M. Princevac *"Laboratory Investigation of Air Quality Impact of Distributed Power Generators"* SCCUR 2009, 1, California State University Dominguez Hills, November 2009

87. H. Pan, M. Princevac, C. Bartolome, R. Edwards *"Observed wind, turbulence, traffic flow and surface PM2.5 concentrations in 5 different built-environments"* SoCal Symposium of Fluid Mechanics, Irvine, CA, April 2010

86. C. Bartolome, M. Princevac, A. Venkatram, S. Mahalingam "Modeling and Parameterization of Superfog" SoCal Symposium of Fluid Mechanics, Irvine, CA, April 2010

85. T. Maynard, M. Princevac *"An Application of a Simple Free Convection Model to the Fire Flickering Phenomenon"* SoCal Symposium of Fluid Mechanics, Irvine, CA, April 2010

84. E. Gutierrez, S. Pournazeri, M. Princevac "Measuring the Final Rise of Pollution Emitted From a Stationary Point Source" Symp. for UG research, scholarship and creative activity, Riverside, CA, May 2010

83. M. Princevac, H. Pan, C. Bartolome, "Field, Laboratory and Numerical Study of Turbulent Dispersion in Built Environments," September, *9th European Meteorological Society (EMS) Annual Meeting*, Toulouse, France, September 2009.

82. M. Princevac, H. Pan, R. Edwards, M. Boarnet, J. Wu, "Water Channel Modeling of Flow and Dispersion of Traffic Related Emissions in Southern Californian Cities," July, *PHYSMOD 2009 International Workshop on Physical Modelling of Flow and Dispersion Phenomena*, Sint-Genesius-Rode, Belgium, August 2009.

81. M. Princevac, H. Pan, R. Edwards, A. Sfazl, M. Boarnet, J. Wu, R. Lejano, "Field, Laboratory and Numerical Study of Turbulent Dispersion in Built Environments Surrounding Major Arterials in Southern Californian Cities," *The Sixth International Symposium on Turbulence and Shear Flow Phenomena*, Seoul, Korea, July 2009.

80. F. Freedman, A. Venkatram, S. Lee, M. Princevac, "Development of AERMOD-ready Meteorological Input Files for the South Coast Air Quality Management District," *A&WMA's 102nd Annual Conference & Exhibition*, Detroit, MI, June 2009, 1, 2009.

79. A. Venkatram, W. Qian, D. Pankratz, M. Princevac, "The Air Quality Impact of Distributed Generation –Field Studies and Modeling," *7th International Conference on Air Quality-Science and Application*, Istanbul, Turkey, March 2009.

77. Y. Zhang, M. Princevac, S. Lee, "Sensible, Latent and Ground Heat Flux Model," *American Meteorological Society, 89th Annual Meeting*, Phoenix, AZ, January 2009, 4 pages, 2009
78. D. Altshuler, M. Princevac, H. Pan, J. Lozano, "PIV Measurements of Hovering Hummingbird," *The Society for Integrative and Comparative Biology (SICB) Annual Meeting*, Boston, MA, January 2009.

75. H. Pan, M. Princevac, R. Edwards, A. Sfazl, M. Boarnet, J. Wu, R. Lejano, "Field, Laboratory and Numerical Study on Flow and Dispersion of PM2.5 in Southern Californian Cities," *American Meteorological Society, 89th Annual Meeting*, Phoenix, AZ, January 2009, 4 pages, 2009

76. X. Li, S. Chen, M. Princevac, A. Venkatram, D. Pankratz, "Plume Rise and Ground-Level Concentration of Emission from a Distributed Power Generation Unit: Field Observations and Water Channel Modeling," *American Meteorological Society, 89th Annual Meeting*, Phoenix, AZ, January 2009.

74. W. Qian, M. Princevac, A. Venkatram, "Relationships between urban and suburban micrometeorological variables," *American Meteorological Society, 89th Annual Meeting*, Phoenix, AZ, January 2009.

73. Q. Jing, D. Pankratz, M. Princevac, A. Venkatram, "Modeling Dispersion of Buoyant Releases in an Urban Area," *American Meteorological Society, 89th Annual Meeting*, Phoenix, AZ, January 2009.

72. J. Bühler, M. Princevac, A. Schleiss, "Forced plumes on an incline," *2nd International Symposium on Shallow Flows*, Hong Kong, China, December 2008.

71. C. Bartolome, X. Li, S. Chen, M. Princevac, "Laboratory Modeling of the Distributed Power Generation," *SCCUR 2008, Cal Poly Pomona*, Pomona, CA, November 2008.
70. J. Lozano, W. Tachajapong, H. Pan, A. Swanson, C. Kelley, M. Princevac, S. Mahalingam, "Experimental Investigation of the Velocity Field in a Controlled Wind-aided Propagating Fire Using Particle Image Velocimetry," *The International Association for Fire Safety Science (IAFSS) symposium*, Karlsruhe, Germany, September 2008.
69. M. Princevac, X. Li, H. Pan, "Modeling of Urban Canopy Flows in a Water Channel," *12th Asian Congress of Fluid Mechanics*, Daejeon, Korea, August 2008.
68. C. Bartolome, M. Princevac, "Laboratory Modeling of the Air Quality Impact of the Distributed Power Generation," *UGRC 2008*, Riverside, CA, May 2008.
67. J. Gutinerez, M. Princevac, "Near Source Modeling of Emissions from Major Arterials in Southern Californian Cities," *UGRC 2008*, Riverside, CA, May 2008.
66. H. Pan, J. Lozano, W. Tachajapong, A. Swanson, C. Kelley, S. Mahalingam, M. Princevac, "Wind tunnel study of particulate emissions, fire spread and velocity field within the flame," *The 2008 Spring Meeting of the Western States Section of the Combustion Institute*, Los Angeles, CA, March 2008.
65. A. Swanson, C. Kelley, B. Baldauf, F. Fendell, S. Mahalingam, M. Princevac, J. Lozano, W. Tachajapong, H. Pan, "Northrop Grumman Fire Tunnel Facility: Physical characteristics, velocity measurements and particulate matter emission in controlled fire propagation over level terrain," *Fire in the Southwest: Integrating Fire into Management of Changing Ecosystems, The Association for fire ecology regional conference*, Tucson, AZ, January 2008.
64. M. Princevac, H. Pan, X. Li, M. Brown, "Flow Pattern Within Cubical Arrays Of Obstacles - Water Channel Results," *American Physical Society, Division of Fluid Mechanics 60th Annual Meeting (APS/DFD07)*, Salt Lake City, UT, December 2007.
63. X. Li, N. Zimmerman, M. Princevac, "Local Imbalance of Turbulent Kinetic Energy and the Dissipation Parameterization in Surface Layer," *The Fifth International Symposium on Environmental Hydraulics (ISEH V)*, Tempe, AZ, December 2007.
62. X. Li, H. Pan, T. Cole, M. Princevac, "Flows Inside A Simple Urban Array: Water Channel Modeling Results," *Fifth International Symposium on Environmental Hydraulics*, Tempe, AZ, December 2007.
61. J. Bühler, M. Princevac, "New Velocity And Buoyancy Scales For Gravity Currents And Jet-Like Flows," *Fifth International Symposium on Environmental Hydraulics*, Tempe, AZ, December 2007.
60. H. Pan, X. Li, M. Brown, J. Baik, S. Park, M. Princevac, "Mean flow pattern through a simple mock urban array – water channel experiments and modeling," *Seventh Conference on Coastal Atmospheric and Oceanic Prediction and Processes joint with the Seventh Symposium on the Urban Environment, American Meteorological Society*, San Diego, CA, September 2007.
59. A. Venkatram, W. Qian, T. Zhan, M. Princevac, "Comparison Of Methods To Generate Meteorological Inputs For Modeling Dispersion In Coastal Urban Areas," *29th NATO/SPS International Technical Meeting (ITM) on Air Pollution and its Application*, Aveiro, Portugal, September 2007.
58. A. Venkatram, M. Princevac, A. Luhar, W. Qian, "Estimating Meteorological Inputs For Dispersion Modeling In Urban Areas," *11th International Conference On Harmonization Within Atmospheric Dispersion Modelling For Regulatory Purposes*, Cambridge, UK, July 2007, 5 pages, 2007
57. H. Pan, X. Li, M. Princevac, "Piv And Plif Measurements Of Model Urban Flows In A Water Channel," *5th Joint ASME/JSME Fluids Engineering Conference*, San Diego, CA, July 2007.
56. J. Buhler, M. Princevac, "A Common Depth Scale For Gravity Currents And Open Channel Flows," *32nd Congress of the International Association of Hydraulic Engineering and Research*, Venice, Italy, July 2007.
55. X. Li, N. Zimmerman, M. Princevac, "Characterization Of Turbulent Kinetic Energy Budget In The Atmospheric Surface Layer," *16th Conference on Atmospheric and Oceanic Fluid Dynamics*, Santa Fe, NM, June 2007.

54. J. Grubbs, S. Pederson, N. Zimmerman, M. Princevac, "Measurement of Surface Fluxes Along Rural-Urban Transect," *Symposium for Undergraduate Research, Scholarship and Creative Activity*, Riverside, CA, May 2007.

53. X. Li, N. Zimmerman, M. Princevac, "Imbalance of Turbulent Kinetic Energy in the Atmospheric Surface Layer," *1st Southern California Symposium on Flow Physics*, Pasadena, CA, April 2007.

52. H. Pan, X. Li, M. Princevac, "Flow Patterns and Dispersion Phenomena in a Simple Urban Environment," *1st Southern California Symposium on Flow Physics*, Pasadena, CA, April 2007.

51. J.C.R. Hunt, M. Princevac, D.J. Carruthers, H.J.S. Fernando, "Modeling Slope Flows and Dispersion in Complex Terrain with Weak Geostrophic Winds," *European Geosciences Union General Assembly 2007*, Vienna, Austria, April 2007.

50. N. Zimmerman, M. Princevac, "Characterization of the Turbulent Kinetic Energy Budget," *Souther California Conference for Undergraduate Research (SCCUR) 2006*, Los Angeles, CA, November 2006.

49. J. Grubbs, M. Princevac, "Water Channel Modeling of Environmental Flows," *2006 SCCUR*, Los Angeles, CA, November 2006.

48. H.J.S. Fernando, M. Princevac, R. Calhoun and J.C.R. Hunt, "Transport and Small-Scale Mixing in Topographically Dominated Stably Stratified Flows," *6th International Symposium on Stratified Flows (ISSF)*, Perth, Australia, November 2006.

47. J. Bühler, M. Princevac, "Tracer-based width and velocity scales for jet-like flows," *6th International Symposium on Stratified Flows (ISSF)*, Perth, Australia, November 2006.

46. H.J.S. Fernando, M. Princevac, J.C.R. Hunt, C. Dumitrescu, "Katabatic Flow Over Long Slopes: Velocity Scaling, Flow Pulsations and Effects of Slope Discontinuities," *12th Conference on Mountain Meteorology*, Santa Fe, NM, August 2006.

45. M. Princevac, H.J.S. Fernando, A. Mills, "Morning Breakup of a Nocturnal Cold Pool," *12th Conference on Mountain Meteorology*, Santa Fe, NM, August 2006.

44. M. Princevac, T. Cole, X. Li, "Laboratory modeling of a simple urban environment," *AAAS Pacific Division Meeting*, San Diego, CA, June 2006.

43. T. Cole, X. Li, C. Eising, M. Princevac, "Turbulence And Channeling In A Simple Urban Environment," *AMS 17th Symposium on Boundary Layers and Turbulence*, San Diego, May 2006.

42. M. Princevac, S. Lee, H. Fernando, E. Pardyjak, P. Monti, "A Mixing Parameterization for Stratified Turbulence in Geophysical Flows," *The 13th Ocean Sciences Meeting*, Honolulu, Hawaii, February 2006.

41. X. Li, M. Princevac, "Interactions of Urban and Marine Boundary Layers During the Wilmington 2005 Urban Dispersion Study," *Sixth Symposium on the Urban Environment*, Atlanta, GA, January 2006.

40. C. Eising, T. Cole, M. Princevac, "Laboratory Modeling of Urban Flow," *2005 Southern California Conference on Undergraduate Research*, Riverside, CA, November 2005.

39. N. Zimmerman, X. Li, M. Princevac, "Sea Breeze Patterns During the Wilmington 2005 Urban Dispersion Study," *2005 Southern California Conference on Undergraduate Research*, Riverside, CA, November 2005.

38. X. Li, M. Princevac, R. Calhoun, "Accuracy of a Coherent Doppler Lidar for the Urban Boundary Layer Measurements," *Proceedings of IMECE2005, ASME International Mechanical Engineering Congress and Exposition, November 5-11, 2005 Orlando, Florida*, Orlando, FL, November 2005.

37. M. Princevac, P. Diagne, R. Calhoun, "LIDAR based Measurements of Turbulent Dissipation above Urban Areas," *13th Symposium on Meteorological Observations & Instrumentation, 20-23 June 2005, Savannah, GA*, 1.3, Savannah, GA, June 2005.

36. R. Calhoun, A. Wieser, M. Princevac, C. Kottmeier, "Comparison of lidar data with tower, profiler, radiosonde, and tethersonde data," *2nd Symposium on Lidar Atmospheric Applications*, San Diego, CA, January 2005.

35. H. Fernando, M. Princevac, "Turbulent Entrainment into Natural Gravity-Driven Flows," *American Physical Society, The 57th Annual Meeting of the Division of Fluid Dynamics*, Seattle, WA, November 2004.

34. R. Calhoun, R. Heap, M. Princevac, J. Sommer, H. Fernando, "Measurement of winds flowing toward an urban area using coherent doppler lidar," *Fifth Symposium on the Urban Environment*, Vancouver, BC, Canada, August 2004.

33. R. Heap, R. Calhoun, M. Princevac, J. Sommer, "Lidar Measurements of atmospheric flow through a downtown cluster of high-rise buildings," *Fifth Symposium on the Urban Environment*, Vancouver, BC, Canada, August 2004.

32. D. Zajic, H. Fernando, M. Princevac, R. Calhoun, "Flow and turbulence in urban canopies," *Fifth Symposium on the Urban Environment*, Vancouver, BC, Canada, August 2004.

31. J. Holeman, M. Princevac, S. Grossman-Clarke, S. Lee, H. Fernando, R. Calhoun, "Joint urban 2003 surface energy budget measurements and analysis," *XXI ICTAM*, Warsaw, Poland, August 2004.

30. M. Princevac, R. J. Calhoun, H. Fernando, "Doppler-LIDAR Deployment During JU2003 Experiment," *XXI ICTAM*, Warsaw, Poland, August 2004.

29. M. Princevac, H. J. S. Fernando, P. Monti, "On quantifying waves and turbulence contributions to momentum and buoyancy transports in katabatic flows," *11th Conference on Mountain Meteorology*, Mt. Washington Valley, NH, June 2004.

28. H. J. S. Fernando, M. Princevac, E. Pardyjak, A. Dato, "The decay of convective turbulence during evening transition period," *11th Conference on Mountain Meteorology*, Mt. Washington Valley, NH, June 2004.

27. M. Princevac, H. J. S. Fernando, "Initial stage of upslope flow development on inclined surfaces," *Tenth Asian Congress of Fluid Mechanics*, Peradeniya, Sri Lanka, May 2004.

26. M. Princevac, R. Calhoun, D. Zajic, J. E. Holeman, R. Heap, H. J. S. Fernando, "Arizona State University's Contribution to the Joint Urban 2003 Experiment: An Overview," *Tenth Asian Congress of Fluid Mechanics*, Peradeniya, Sri Lanka, May 2004.

25. R. Calhoun, R. Heap, J. Sommer, M. Princevac, J. Peccia, H. Fernando, "Tracking aerosol plumes-lidar, modeling, and in situ measurement," *SPIE Defense & Security Symposium, Sensors, Command, Control, Communications, and Intelligence Technologies for Homeland Security and Homeland Defense*, Orlando, FL, April 2004.

24. M. J. Brown, D. Boswell, G. Streit, M. Nelson, T. McPherson, T. Hilton, E. R. Pardyjak, S. Pol, P. Ramamurthy, B. Hansen, P. Kastner-Klein, J. Clark, A. Moore, D. Walker, N. Felton, D. Strickland, D. Brook, M. Princevac, D. Zajic, R. Wayson, J. MacDonald, G. Fleming, D. Storwold, "Joint Urban 2003 street canyon experiment," *American Meteorological Society, 84th AMS Annual Meeting 2003*, Seattle, WA, January 2004.

23. R. K. Newsom, D. Ligon, R. Calhoun, E. Creegan, R. Heap, M. Princevac, "First retrieval from dual Doppler – JU2003," *BCACIMO 2003*, Monterey, CA, September 2003.

22. J. C. R. Hunt, S. Zilitinkevich, F. Nieuwstadt, H. J. S. Fernando, M. Princevac, "Eddy structure and mean flow effects in strong convection," *EGS-AGU-EUG Joint Assembly*, Nice, France, April 2003.

21. H. J. S. Fernando, M. Princevac, J. C. R. Hunt, "Unsteady katabatic winds on mountain slopes," *EGS-AGU-EUG Joint Assembly*, Nice, France, April 2003.

20. M. Princevac, A. Mills, H. J. S. Fernando, W. C. Chan, "Destruction of cold pools in complex terrain air basins," *Bull. American Physical Society 2002 Division of Fluid Dynamics*, San Diego, CA, November 2002.

19. M. Princevac, G. B. Delgado, H. J. S. Fernando, "Flows in complex terrain: The generation of anabatic flow on simple slopes. Poster presentation," *Building a Vision for Higher Education in Science, Technology, Engineering and Math*, Albuquerque, NM, September 2002.

18. S. M. Lee, M. Sinesi, M. Princevac, D. Zajic, H. J. S. Fernando, J. Anderson, "A numerical study on the spatial and temporal variation of ozone within the Phoenix valley," *6th Annual George Mason University Transport and Dispersion Modeling Workshop*, Fairfax, VA, July 2002.

17. M. Princevac, P. Monti, H. J. S. Fernando, T. A. Kowalewski, E. R. Pardyjak, "Turbulence and mixing in the nocturnal boundary layer over a slope – VTMX field program results," *10th Conference on Mountain Meteorology*, Park City, UT, June 2002.

16. E. R. Pardyjak, M. J. Brown, M. A. Nelson, D. Zajic, M. Princevac, C. Biltoft, J. C. Klewicki, "Buildings effects on thermal stratification during the MUST trials," *American Meteorological Society, Fourth Symposium on the Urban Environment 2002*, Norfolk, VA, May 2002.

15. M. Brown, E. Pardyjak, D. Zajic, M. Princevac, G. Streit, C. Biltoft, "The MUST field experiment: Mean and Turbulent Wind Fields at the Upstream edge of a building array," *American Meteorological Society, Fourth Symposium on the Urban Environment 2002*, Norfolk, VA, May 2002.

14. S. Lee, M. Sinesi, M. Princevac, D. Zajic, J. L. McCulley, H. J. S. Fernando, J. Anderson, "A study on vertical distribution of ozone in the PBL of the Phoenix Valley," *12th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association*, Norfolk, VA, May 2002.

13. D. Zajic, M. Princevac, J. Kim, H. J. S. Fernando, J. J. Baik, "Flow and turbulence surrounding a building cluster," *American Meteorological Society, Fourth Symposium on the Urban Environment 2002*, Norfolk, VA, May 2002.

12. M. Princevac, H. J. S. Fernando, W. C. Chan, T. A. Kowalewski, P. Monti, J. Anderson, "Slope flow measurements during vertical transport and mixing (VTMX) Field Experiment – Salt Lake City 2000," *3rd International Symposium on Environmental Hydraulics*, Tempe, AZ, December 2001.

11. W. C. Chan, H. J. S. Fernando, M. Princevac, "Daytime complex terrain transport – A criterion for the generation of anabatic flow," *3rd International Symposium on Environmental Hydraulics*, Tempe, AZ, December 2001.

10. T. Kowalewski, P. Monti, W. C. Chan, M. Princevac, H. J. S. Fernando, "Vertical transport and mixing in the Salt-Lake Basin," *3rd International Symposium on Environmental Hydraulics*, Tempe, AZ, December 2001, 6 pages, 2001.

9. H. J. S. Fernando, M. Princevac, J. C. R. Hunt, W. C. Chan, "Studies on up-slope flows in complex topographies," *Bull. American Physical Society, 2001 Division of Fluid Dynamics*, San Diego, CA, November 2001, 1 pg, 2001.

8. M. Princevac, H. J. S. Fernando, W. C. Chan, "The generation of anabatic flows: theoretical modeling and experiments," *Bull. American Physical Society. 2001 Division of Fluid Dynamics*, San Diego, CA, November 2001, 1 pg, 2001.

7. M. Princevac, W. C. Chan, H. J. S. Fernando, "Flow in complex terrain: studies on anabatic flows," *International Workshop on Physical Modeling of Flow and Dispersion Phenomena*, Hamburg, September 2001, 4 pgs, 2001.

6. M. Princevac, W. C. Chan, "ASU contribution to the vertical transport and mixing (VTMX) field experiment-Salt Lake City 2000," *17th Arizona Fluid Mechanics Conference*, Tucson, AZ, February 2001, 1 pg, 2001.

5. F. Yu, N. S. Berman, M. Princevac, W. C. Chan, "Nocturnal boundary layer structure in Salt Lake Valley during VTMX field experiment," *17th Arizona Fluid Mechanics Conference*, Tucson, AZ, February 2001, 1 pg, 2001.

4. W. C. Chan, M. Princevac, "A criterion for the generation of anabatic flow," *17th Arizona Fluid Mechanics Conference*, Tucson, AZ, February 2001, 1 pg, 2001.

3. H. J. S. Fernando, M. Princevac, J. C. R. Hunt, E. Pardyjak, "Thermal circulation in complex terrain: A case of urban fluid mechanics," *5th International Symposium of Stratified Flows*, British Columbia, CA, July 2000, 649-654, 2000.

2. M. Princevac, H. J. S. Fernando, D. L. Boyer, "Modeling of complex terrain flow processes," *Air and Waste Management Association 93rd Annual Conference*, Salt Lake City, UT, June 2000, 10 pgs, 2000.

1. M. Princevac, "Complex terrain," *16th Arizona Fluid Mechanics Conference*, Tempe, AZ, February 2000, 1 pg, 2000.

Exhibit 2

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(12) **United States Patent**
Caro et al.

(10) **Patent No.: US 7,258,710 B2**
(45) **Date of Patent: Aug. 21, 2007**

(54) **MARITIME EMISSIONS CONTROL SYSTEM**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

1,013,358 A * 1/1912 Andrews 454/3
1,439,226 A * 12/1922 Clarke 52/66
4,099,452 A * 7/1978 Costen 454/39
4,442,766 A * 4/1984 Hawkins 100/35
4,637,300 A * 1/1987 Cole 454/1
5,092,226 A * 3/1992 McCloskey 454/5
5,281,246 A * 1/1994 Ray et al. 55/302
5,460,301 A 10/1995 Ebinger et al.
5,613,990 A * 3/1997 Diachuk 55/383
5,622,538 A * 4/1997 Diachuk 55/383
5,687,773 A * 11/1997 Ryan et al. .... 138/96 R
5,823,218 A * 10/1998 Schlecht et al. 137/2
5,842,918 A * 12/1998 Cowen 454/12
5,980,343 A * 11/1999 Rolinski .... 440/89 R
6,022,389 A * 2/2000 Vross et al. 55/315.1
6,244,918 B1 * 6/2001 Cameron .... 440/89 R
6,332,308 B1 * 12/2001 Miller 55/385.5
6,463,958 B1 10/2002 Schwing
6,726,736 B2 * 4/2004 Koclejda et al. 55/385.2
6,910,930 B1 * 6/2005 Mitchell .... 440/89 R

* cited by examiner

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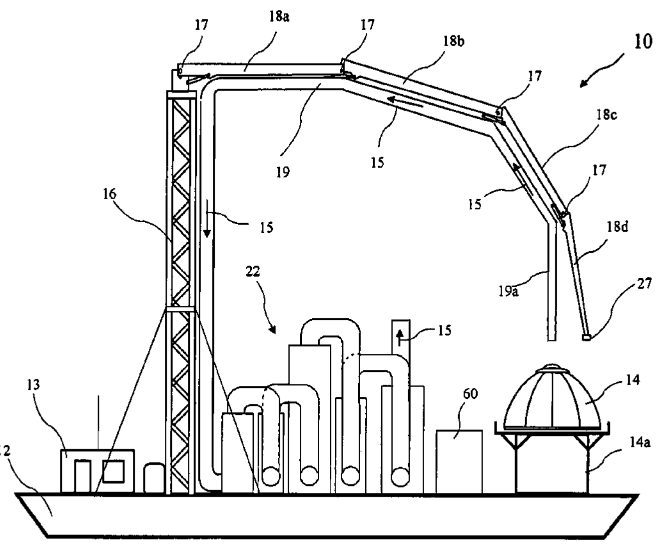
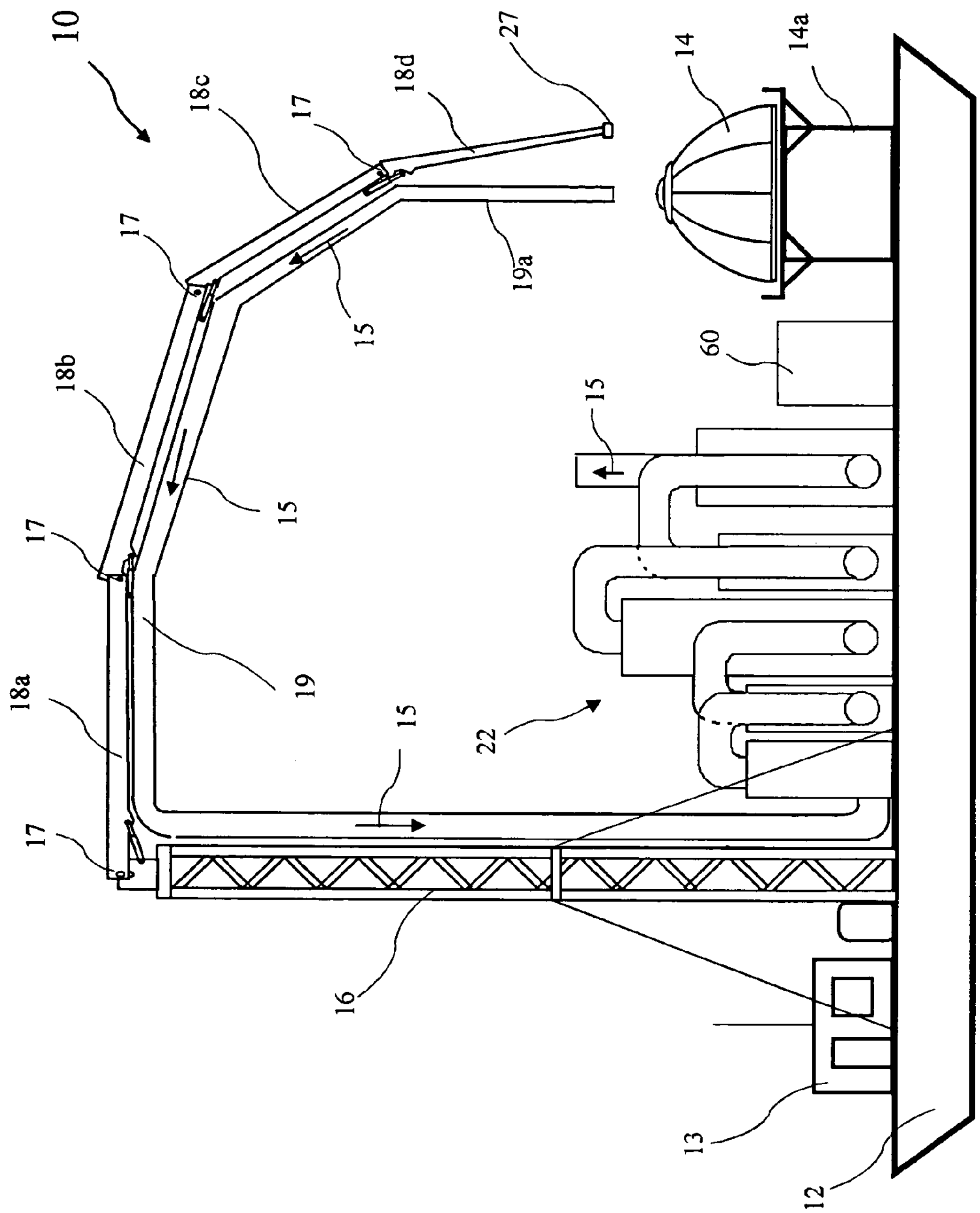
(74) *Attorney, Agent, or Firm*—Kenneth L. Green; Edgar W. Averill, Jr.

(57) **ABSTRACT**

An Advanced Maritime Emissions Control System (AMECS) includes several Exhaust Intake Bonnets (EIBs) of different size and/or shape, an Emissions Capture System (ECS), and an Advanced Maritime Emissions Control Unit (AMECU) mounted on an Unpowered Seagoing Barge (USB). The EIB includes a cage formed by downward curved ribs, a shroud which is lowerable to cover the ribs, a belt near a lower edge of the EIB for retaining and sealing the EIB to a stack, and a mechanism for tightening the lower edge of the EIB (and thus the belt) around the stack. The ECS lifts one of the several EIBs onto the stack of an Ocean Going Vessel (OGV). Exhaust from the stack is drawn through a large diameter duct to the AMECU. The AMECU processes the exhaust through multiple treatment stages. The stages include pre conditioning the exhaust, oxidizing, reducing, polishing, and precipitating.

35 Claims, 6 Drawing Sheets

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18c
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18d
27
14
14a
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19a
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18b
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15
17
15
19
18a
15
22
17
16
13
12

FIG. 1

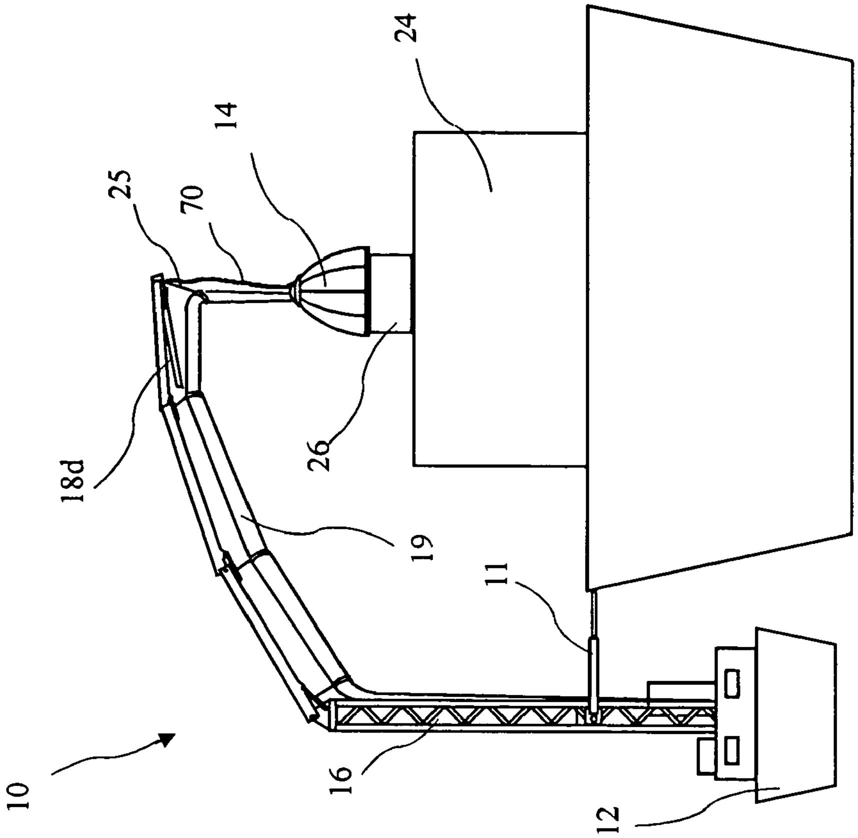


FIG. 2B

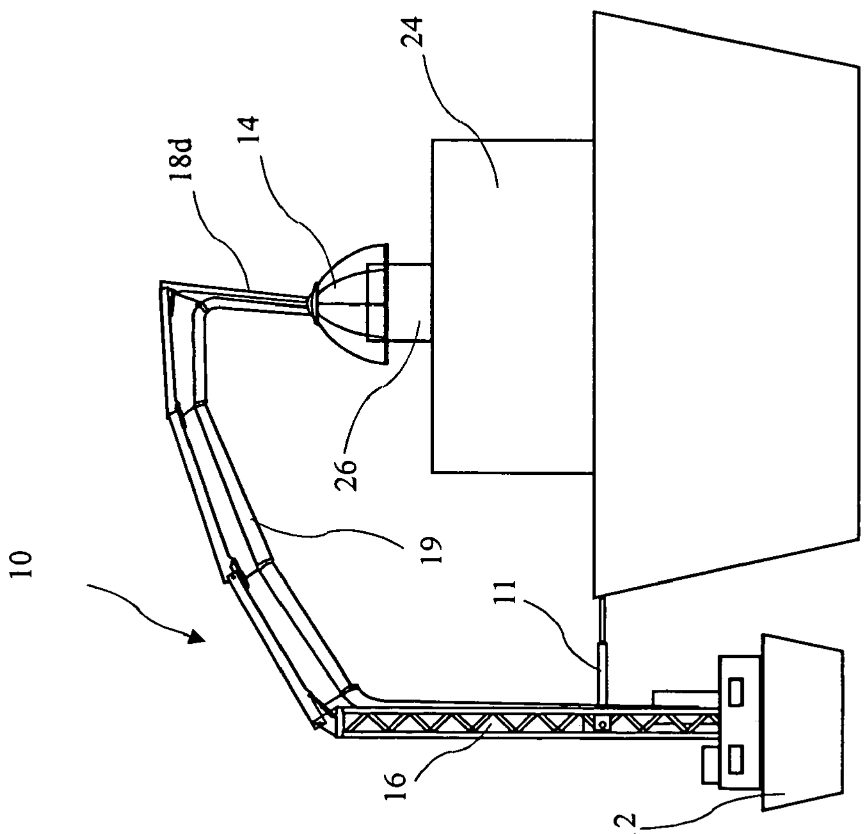


FIG. 2A

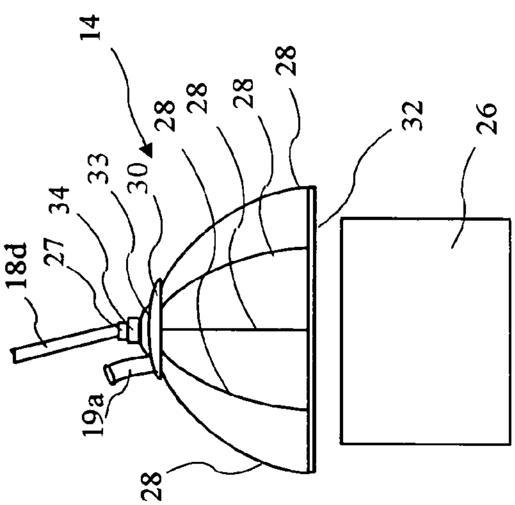


FIG. 3A

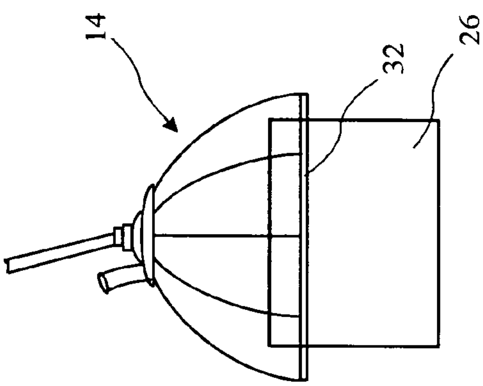


FIG. 3B

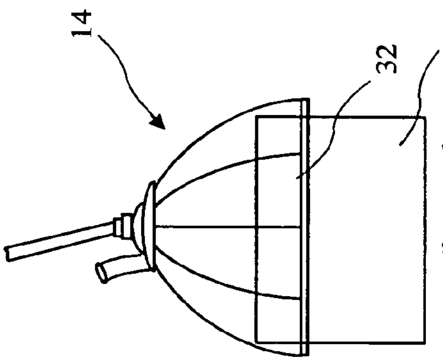


FIG. 3C

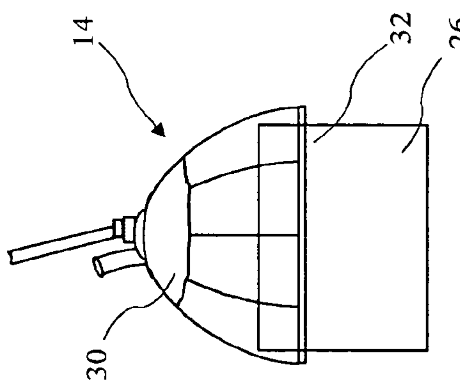


FIG. 3D

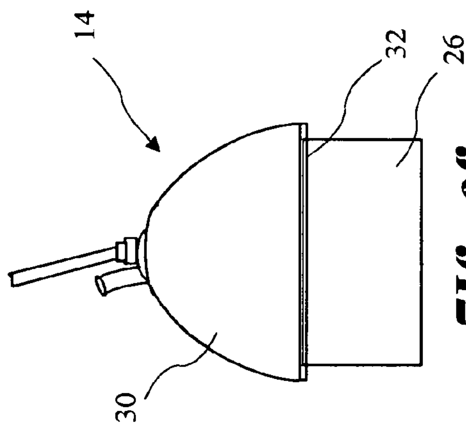


FIG. 3E

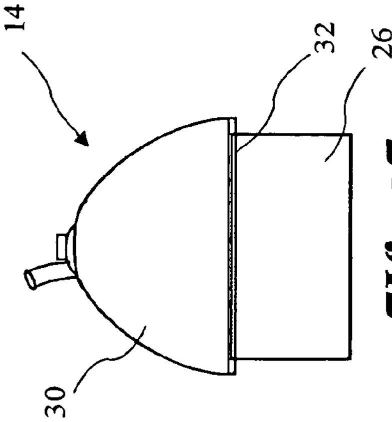
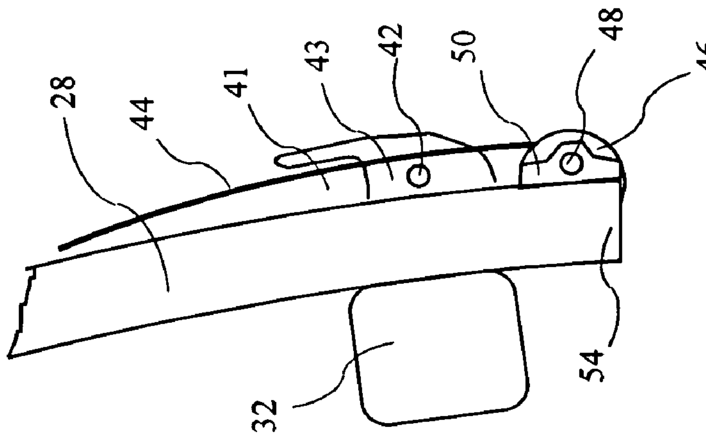


FIG. 3F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44
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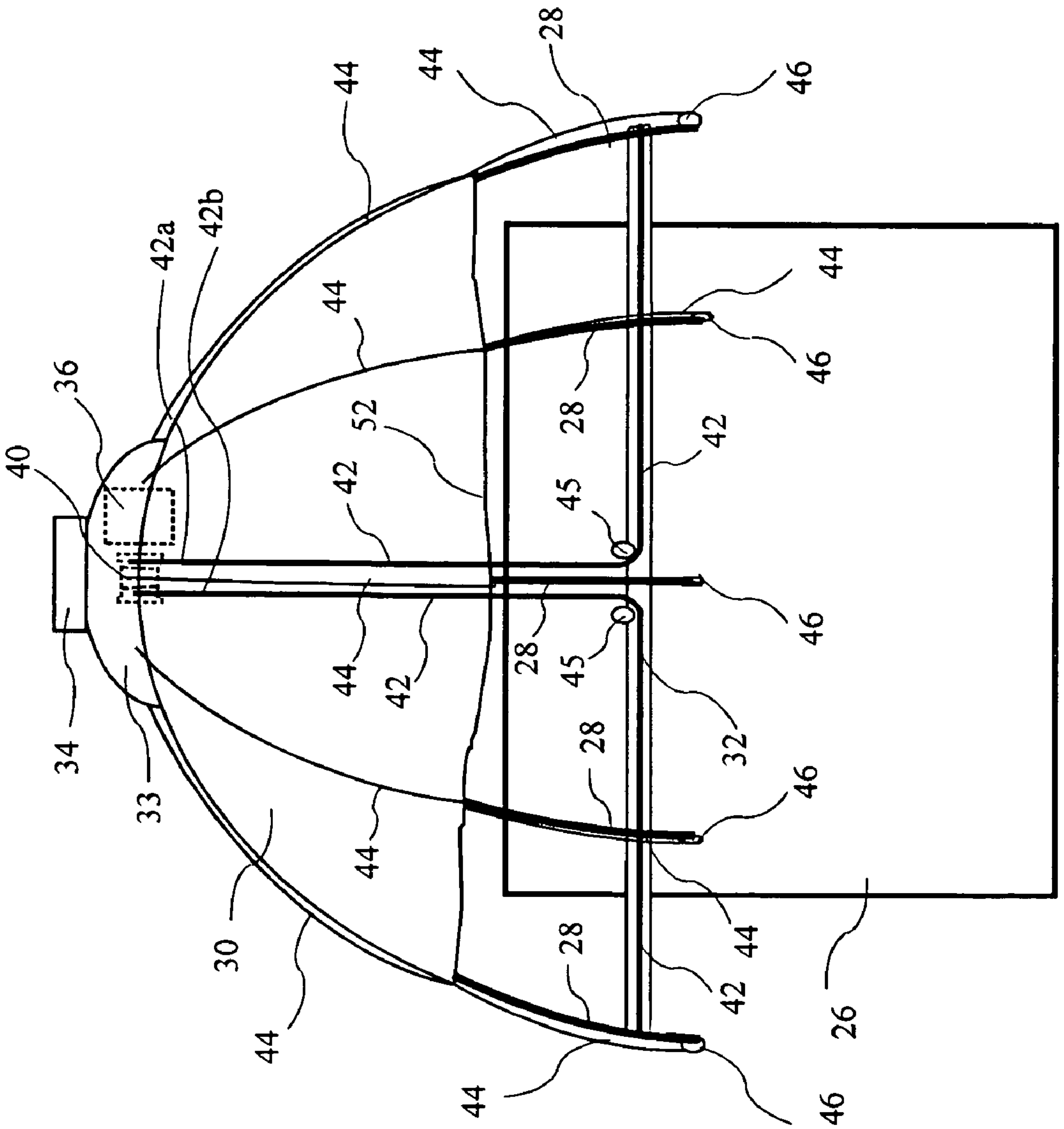
46
32
54

FIG. 4A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42b
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44
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44
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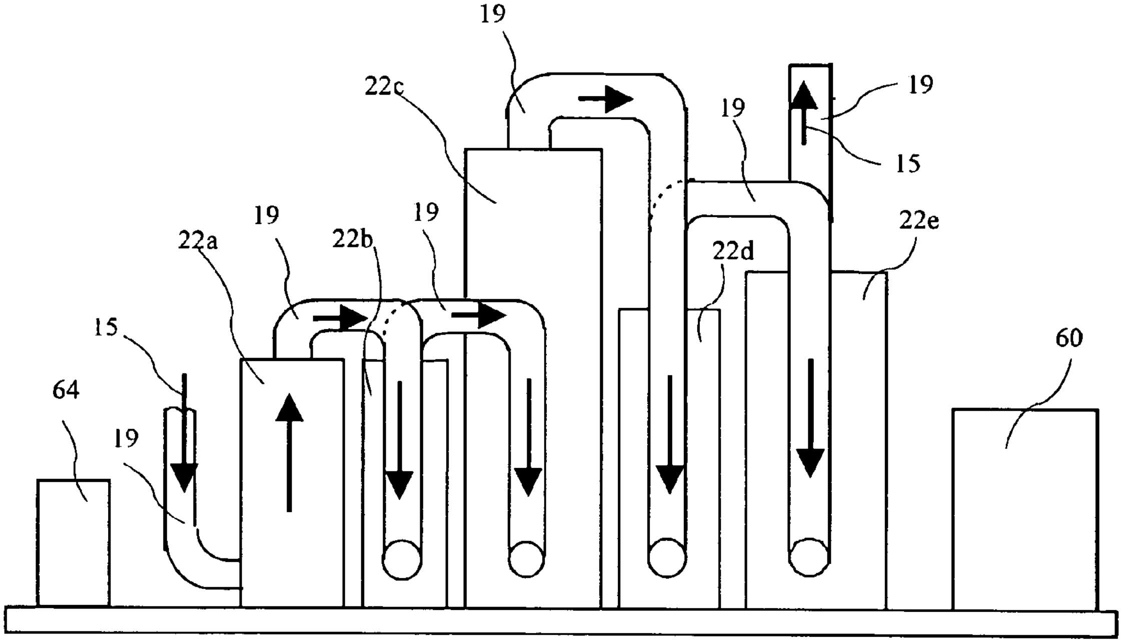
46
44
44

FIG. 4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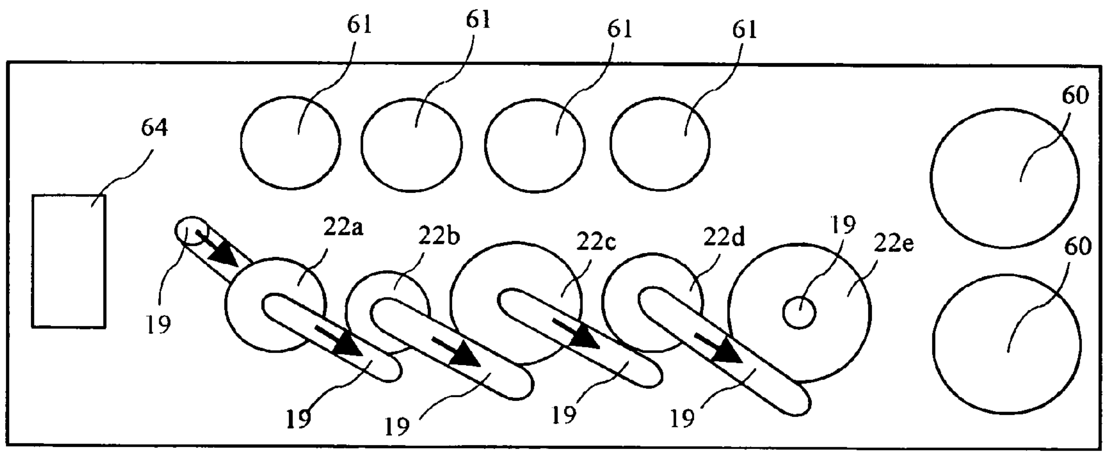
19
15
19
22a
22b
19
22d
22e
15
60
64
19

FIG. 5A


61
61
61
61
60
64
22a
22b
22c
22d
19
22e
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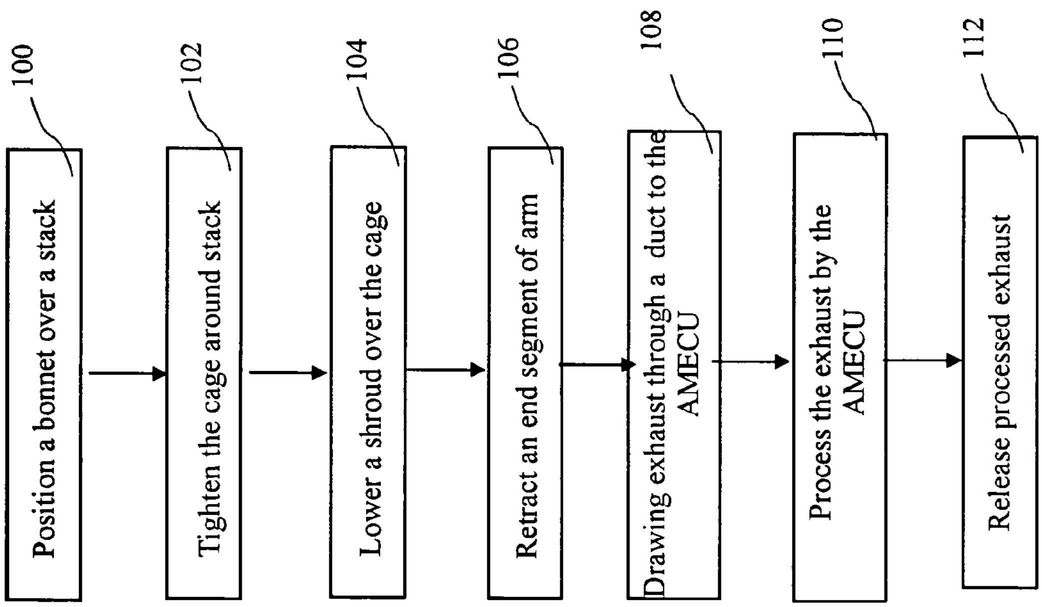
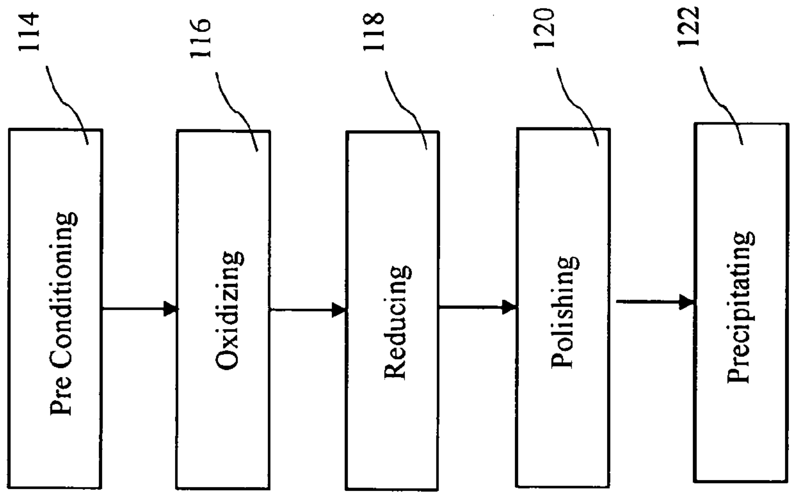
19
19
19
19
19

FIG. 5B



100
Position a bonnet over a stack
102
Tighten the cage around stack
104
Lower a shroud over the cage
106
Retract an end segment of arm
108
Drawing exhaust through a duct to the AMECU
110
Process the exhaust by the AMECU
112
Release processed exhaust

FIG. 6



114
Pre Conditioning
116
Oxidizing
118
Reducing
120
Polishing
122
Precipitating

FIG. 6A

MARITIME EMISSIONS CONTROL SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to the reduction of emissions from Ocean Going Vessels (OGVs), and more particularly to a system for capturing and processing emissions from OGVs in the vicinity of a port.

A substantial quantity of pollutants are produced by burning fuel in OGVs. The pollutants produced when an engine burns bunker an/or diesel fuel is a complex mixture of thousands of gases and fine particles, commonly known as soot, which contains more than forty toxic air contaminates. These contaminates include arsenic, benzene, and formaldehyde along with other ozone-forming pollutants that are components of smog and acid rain, such as carbon dioxide (CO_2), sulphur dioxide (SO_2), and nitrogen oxides (NO_x). An OGV may create and exhaust as much NO_x as 12,500 automobiles or as an oil refinery, and thus is a substantial health risk to port workers and residents of surrounding communities, and may physically damage structures and equipment.

BRIEF SUMMARY OF THE INVENTION

The present invention addresses the above and other needs by providing an Advanced Maritime Emissions Control System (AMECS) comprising a multiplicity Exhaust Intake Bonnets (EIBs), an Emissions Capture System (ECS) comprising a tower and actuating arm, an Advanced Maritime Emissions Control Unit (AMECU), and a duct connecting the EIB to the AMECU. The AMECS is preferably mounted on an Unpowered Seagoing Barge (USB).

The AMECS is deployed when an Ocean Going Vessel (OGV) is at sea, for example, when the OGV is approaching the three miles limit. The USB carrying the AMECS, is assisted by a tug to meet the OGV at a point off the coast. As the USB approaches the OGV, the tug positions the USB along the OGV side opposite to the side from which the OGV will be unloaded. Once alongside the OGV, the USB is secured to the OGV, and preferably, a stabilization arm is extended between the tower and the OGV, to absorb shock and provide stability for the ECS. The ECS is then activated, hosting an EIB selected from a multiplicity of EIBs shaped to accommodate the particular ship's stack configuration, onto the stack. An EIB attachment mechanism (preferably including a soft belt which may be tightened around the stack by drawing a cord) is then actuated to create a soft attachment between the EIB and the ship's stack. Once the USB is secured to the OGV, and EIB is properly attached to the stack, the AMECU is started thereby forming a pressure drop in the duct. This begins the process of directing the stack exhaust into the AMECU residing on the USB. A shroud is then lowered from a upward end of the EIB over the EIB, thereby forming a seal around the stack. An end segment of the articulating arm is then retracted, leaving a flexible end section of the duct connected to the EIB. Thus attached, the assembly is able to sustain movement between of the USB relative to the OGV of approximately five vertical feet and approximately five horizontal feet, without adversely affecting the attachment of the EIB or placing too great a stress on the stack.

The OGV and attached USB are then guided into port and docked. The AMECS system may remain alongside the OGV, ensuring that the exhausted emissions are reduced as much as existing technology can provide. Alternatively, a shore based AMECS may be connected to the stack while the OGV is docked. When the OGV is ready for departure, it is guided out of the harbor and out to sea a distance of, for example, approximately three miles, where the EIB is detached and the OGV is released allowing it to proceed to its next destination. To release the EIB, the blowers are shut down, the shroud retracted, the articulating arm reattached, and the tension to the cord removed allowing the belt to relax, thereby permitting the EIB to be removed. The AMECS is then returned to its serving dock where any stored solid contaminates are removed and the system readied for the next OGV to arrive.

In accordance with one aspect of the invention, there is provided an Advanced Maritime Emissions Control System (AMECS) for Ocean Going Vessels (OGVs) comprising a barge, a tower mounted to the barge, an articulating arm mounted to the tower, an Exhaust Intake Bonnet (EIB) attached to a last segment of the articulating arm, an Advanced Maritime Emissions Control Unit (AMECU), and a duct for carrying the exhaust from the EIB to the AMECU. The EIB captures the exhaust from an OGV stack, and the AMECU processes the exhaust. The EIB is selected from a set of several EIBs of different sizes and/or shapes.

An exemplar AMECU **22** includes two primary treatment systems. The first system accomplishes reduction of nitrogen oxides (NOx) as its primary purpose, and the second system focuses on the reduction of Particulate Matter (PM). Each system may have as a secondary benefit, the reduction of other atmospheric contaminants.

An exemplar first system is a four-stage particulate/NOx/SO_2 scrubber system. The first system includes a Pre Conditioning Chamber (PCC) quench vessel first stage, an oxidation column second stage, a reduction column third stage, and a caustic (or polishing) column fourth stage. An exemplar second system is a wet electrostatic precipitation system to further reduce the concentration of PM.

Various numbers of stages, functions of the stages, orders of the stages, or contaminant reduction processes in any or all of the stages may be utilized to construct an AMECU. Alternative exemplar first systems may include, but are not limited to, Selective Catalytic Reactors (SCR) and various emerging technologies such as thermal or plasma enhanced catalytic or non-catalytic NOx removal or NOx conversion systems, and other technologies to reduce NOx or convert NOx into more benign compounds.

Alternative exemplar second systems may include, but are not limited to, washers, ionizing wet scrubbers, wet scrubbers, packed column scrubbers, cyclone scrubbers, impingement scrubbers, eductor scrubbers, vortex scrubbers, venturi scrubbers, and others, as well as filters of various types, both passive and dynamic. Some of these devices may also be used as the first stage in a multistage system. An AMECS including any combination of these, or similar devices, is intended to come within the scope of the present invention.

In accordance with another aspect of the invention, there is provided a method for emissions control, the method comprising securing a bonnet over a stack of an Ocean Going Vessel (OGV), drawing exhaust from the stack through a duct to an emissions control system, and processing the exhaust by the emissions control system. Securing the bonnet over the stack comprises positioning a cage over a stack, tightening the cage around the stack, and lowering a shroud over the cage. Processing the exhaust by the emissions control system preferably comprises two primary treatment systems. The first system accomplishes reduction of nitrogen oxides (NOx) as its primary purpose, and the second system focuses on the reduction of Particulate Matter (PM).

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The above and other aspects, features and advantages of the present invention will be more apparent from the following more particular description thereof, presented in conjunction with the following drawings wherein:

FIG. **1** is an Advanced Maritime Emissions Control System (AMECS) according to the present invention.

FIG. **2**A depicts an AMECS deploying a bonnet over a stack of an Ocean Going Vessel (OGV).

FIG. **2**B shows the bonnet over the stack with an end segment of an articulating arm retracted from the bonnet.

FIG. **3**A shows the bonnet positioned above the stack.

FIG. **3**B shows a cage of the bonnet positioned on the stack.

FIG. **3**C shows a lower edge of the cage drawn around the stack.

FIG. **3**D shows a shroud partially lowered over the cage.

FIG. **3**E shows the shroud fully lowered over the cage.

FIG. **3**F shows the bonnet after the articulating arm is detached.

FIG. **4** shows a detailed view of the bonnet over the stack.

FIG. **4**A shows a more detailed view of a lower end of a rib of the cage.

FIG. **5**A is a side view of an Advanced Maritime Emissions Control Unit (AMECU) and associated equipment.

FIG. **5**B is a top view of the AMECU and associated equipment.

FIG. **6** describes a method for emissions control using the AMECS according to the present invention.

FIG. **6**A described the steps for processing emissions.

Corresponding reference characters indicate corresponding components throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE INVENTION

The following description is of the best mode presently contemplated for carrying out the invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of describing one or more preferred embodiments of the invention. The scope of the invention should be determined with reference to the claims.

An Advanced Maritime Emissions Control System (AMECS) **10** according to the present invention is shown generally in FIG. **1**. The AMECS **10** comprises at least one Exhaust Intake Bonnet (EIB) **14**, an Emissions Capture System (ECS), and an Advanced Maritime Emissions Control Unit (AMECU) **22**. The AMECS **10** is preferably mounted on an Unpowered Seagoing Barge (USB) **12**. The ECS comprises a tower **16**, and an articulating arm. The articulating arm comprising four segments **18***a*, **18***b*, **18***c*, and **18***d* connected by joints **17**.

The EIB **14** is preferably one of a multiplicity of shaped EIBs, and more preferably one of a set of four shaped EIBs, each shaped EIB is formed to cooperate with a different size and/or shape stack. The articulating arm segments **18***a*-**18***d* are connected by joints **17**, and the end segment **18***d* is detachably attachable to the EIB **14** using a payload grip **27**. A first camera is attached to the articulating arm, preferably on or near the payload grip **27**, to aid in guiding the payload grip **27** during attachment to the EIB **14**. The EIB **14** is in fluid communication with the AMECU **22** through a duct **19**. An end section of the duct **19** proximal to the EIB **14** is a flexible duct section **19***a*. The duct **19** is connected to the AMECU **22** which processes a flow indicated by arrows **15** to reduce undesirable emissions. When in use, the flow travels from the EIB **14** to the AMECU **22**. When not in use, the EIB **14** may be detached from the articulating arm, and rest on an EIB stand **14***a*.

The articulating arm **18***a*-**18***d* is preferably between fifty feet and one hundred and twenty feet long, and is more preferably approximately one hundred feet long. The duct **19** is preferably between twelve inches and thirty six inches in diameter, and more preferably approximately eighteen inches in diameter, and is preferably made from stainless steel. The EIBs **14** are preferably between fifteen feet and forty feet across, and are suitable for cooperation with stacks of various shape and up to twenty five feet or more across. The tower **16** is preferably between fifty feet and one hundred and twenty feet high, and is more preferably approximately one hundred feet high.

The actuating arm of the present invention is similar to known four section booms used on concrete pump trucks, for example the KVM **32** built by Schwing America Inc. in Saint Paul, Minn. The boom of the KVM **32** is capable of reaching as far as 106 feet vertically, or 93 feet laterally. Booms like the boom of the KVM **32** are described in U.S. Pat. No. 5,460,301 for "Concrete Pump Vehicle" and duct joint geometries for use with booms are described in detail in U.S. Pat. No. 6,463,958 for "Distributing Device for Thick Substance, Especially Concrete." The '301 and '958 patent are herein incorporated by reference.

The AMECS **10** is shown with the EIB **14** residing over a stack **26** of an Ocean Going Vessel **24** in FIG. **2**A. The end segment **18***d* of the actuating arm remains attached to the EIB **14**. Following attachment of the EIB **14** to the stack **26** (described in FIGS. **3**A-**3**F), the end segment **18***d* is detached from the EIB **14** and pivoted to a stored position as shown in FIG. **2**B leaving the flexible portion **19***a* of the duct, and a wire harness **70** attached to the EIB **14**. The duct **19** is supported by a duct support **25** attached to the articulating arm, providing sufficient freedom of movement to allow for some relative motion between the USB **12** and the OGV **24**. Preferably, approximately five feet of lateral and vertical movement is provided.

The position of the USB **12** relative to the OGV **24** is stabilized by a stabilization arm **11** connected between the tower **16** and the OGV **24**. The arm **11** is preferably connected to the tower **16** a little below a midpoint of the tower **16**, and the arm **11** extends approximately horizontally to the OGV **24**. The arm **11** includes a shock absorber to minimize the load on the hull of the OGV **24** and to stabilize the ECS. The tower **16** and articulating arm **18***a*-**18***d* preferably provide sufficient height to place the EIB **14** over the stacks of common OGVs **24**, and more preferably allow sufficient height to place the EIB **14** over the stack of the largest OGVs **24**.

An example of a set of steps of attachment of the EIB **14** to the stack **26** are shown in FIGS. **3**A through **3**F. The EIB **14** including ribs **28** forming a cage-like structure (or frame), a top portion **33** above a shroud **30**, and a belt **32** near the bottom of the ribs **28**, is shown above the stack **26** in FIG. **3**A. The EIB **14** is shown lowered over the stack **26** in FIG. **3**B. The downward end of the EIB **14** is drawn to close around the stack **26** in FIG. **3**C. The shroud **30** is partially lowered over the ribs **28** in FIG. **3**D. The shroud **30** is fully lowered over the ribs **28** in FIG. **3**E. The articulating arm is detached in FIG. **3**F, and the attachment of the EIB **14** to the stack **26** in compete. The steps described above are not exclusive and, for example, the articulating arm may be detached before lowing the shroud **30** over the ribs **28**. The

EIB **14** preferably includes eight to twenty four ribs **28**, and more preferably sixteen ribs **28**.

A detailed view of the EIB **14** is shown in FIG. **4**. A top portion **33** resides above the shroud **30**, and preferably comprises a capture ring assembly **34** at the top of the EIB **14**, which capture ring assembly **34** is used to attach to the EIB **14** to the payload grip **27** (see FIG. **1**). The capture ring assembly **34** is designed to be easily attached and detached from the payload grip **27** (see FIG. **1**). An upper opening of the capture ring assembly **34** has a large aperture, with a self-aligning locking mechanism for engaging the payload grip **27**. Preferably, the payload grip **27** includes a spring latching mechanism which will release locking members into the capture ring assembly **34** when the payload grip **27** is in the proper position.

At least one motor **36** is connected to a hub **40**, the motor **36** and hub **40** preferably residing inside the top portion **33** and are indicted by dashed lines in FIG. **4**. The motor **36** is preferably a constant-torque motor that when activated, tightens a cord **42** thereby compressing the ribs **28** and providing consent pressure for a friction-seal. Cord ends **42***a* and **42***b* of the cord **42** wind around the hub **40**. The cord **42** runs down to belt pulleys **45**, and then around the outside of the ribs **28** through guides **43** to draw the EIB **14** around the stack **26**. The EIB **14** may thus be closed (or compressed) around the stack **26** by winding ends the cord ends **42***a*, **42***b* onto the hub **40**. The motor **36** controls the tension on the cord **42**, to provide an air seal between the EIB **14** and the stack **26**, to firmly hold the EIB **14** on the stack **26**, and to prevent damage to the EIB **14** or the stack **26** during operation of the AMECS **10**.

Shroud cords **44** loop vertically around the outside of the EIB **14** between an upward end and a downward end of the frame, and are attached to the shroud **30** near a lower edge **52** of the shroud **30**, to raise and lower the shroud **30** over the ribs **28**. A shroud notch **41** in the guide **43** provides a seat for the shroud **30** when fully lowered. A second camera and a laser guided positioning system are preferably attached to the EIB **14** to aid in guiding the EIB **14** over the stack **26**. For example, a camera may be mounted in the top portion **33** and pointed down. Video from the camera is used to assist the operator in positioning the EIB **14** over the ships stack **26**. Once the EIB **14** is over the stack **26**, the laser positioning system guides the EIB **14** into its final position around the stack **26**. Alternatively, a system for controlling a boom such as described in U.S. Pat. No. 5,823,218 for "Large Manipulator, Especially for Self-Propelled Concrete Pumps, and Method for Operating it," may be used to automatically position the EIB **14**. The system described in the '218 patent may also be utilized to maintain the position of the articulating arm relative to the stack **26** during operation of the AMECS **10**, and for re-attaching the articulating arm to the EIB **14** when the EIB **14** is to be removed from the stack **26**. The '218 patent is herein incorporated by reference.

The EIB **14** further preferably includes a pressure sensor, and more preferably includes two pressure sensors (a primary sensor and a backup sensor) to provide feedback to a System Operational Control Unit (SOCU), which in turn regulates the speed of a tower blower assembly maintaining a constant negative pressure within the duct **19**, wherein the blower is preferably a centrifugal blower. Maintaining constant pressure assures that nearly all of the exhaust gases are captured and funneled into the AMECU **22** for processing, without adversely affecting engine performance and while compensating for main and auxiliary engine turn-on and startup, and for back pressure in the AMECU **22**.

A more detailed view of a lower portion of a rib **28** is shown in FIG. **4**A. The rib **28** is preferably a springy (i.e., returns to an original shape when released) curved tube, is preferably made from stainless steel or fiberglass, and has a lower end **54**. The rib **28** is required to retain sufficient memory to "spring" back to the open position when the cord **42** is released. A shroud pulley **46** resides on an axle **48** held by a bracket **50** near the lower end **54**. The shroud cord **44** runs around the shroud pulley **46** and through the rib **28**. The shroud cord **44** is preferably drawn by a motor residing above the ribs **28**. In another embodiment, a motor with a hub resides near the lower end **54** of each rib **28**, and the shroud cord **44** is wound around the hub. The belt **32** is shown in cross-sectional view, and the cord **42** is shown running through a guide **43**. While the bracket **50** and guide **43** are shown as two distinct parts in FIG. **4**A, they may be a single bracket/guide.

The shroud **30** is preferably made from a heat and emission resistant material for long life, for example, kevlar® fiber or kapton® polyimide film, and the shroud **30** preferably resists damage from chemicals found in OGV **24** exhaust, and temperatures up to 350 degrees Celsius. The belt **32** is preferably between six inches and fourteen inches thick and ten inches to fourteen inches high, and more preferably approximately ten inches thick and approximately twelve inches high. The belt **32** is preferably made from a soft or sponge-like (i.e., foam) material which provides a degree of air seal between the EIB **14** and the stack **26**, and also retains the EIB **14** onto the stack **26** through surface friction and will not damage the stack. For example, the belt may be made from neoprene or the like material. Alternatively, the belt may be an inflatable belt. The cords **42**, **44** are preferably made from non UV sensitive material, and more preferably from nylon.

A detailed view of an exemplar AMECU **22** layout and associated equipment is shown in FIG. **5**A in side view, and in FIG. **5**B in top view. The exemplar AMECU **22** comprises two primary treatment systems. The first system, accomplishes reduction of nitrogen oxides (NOx) as its primary purpose, and the second system focuses on the reduction of particulate matter (PM). Each system has as a secondary benefit, the reduction of other atmospheric contaminants.

The first system comprises four stages. The first stage comprises a Pre Conditioning Chamber (PCC) quench vessel **22***a*. The second stage comprises oxidation column **22***b*. The third stage comprises reduction column **22***c*. The fourth stage comprises a caustic (or polishing) column **22***d*. The second system comprises a single stage which is a wet electrostatic precipitation system **22***e* which further reduces the concentration of PM.

While a five stage AMECU **22** is described herein, AMECS **10** may include an emissions control unit with a different number of stages, different order of stages, different allocation, and/or, different processing to reduce other emissions, and any AMECS including any of these variations of emissions control units for processing OGV exhaust is intended to come within the scope of the present invention. Arrows **15** indicate the direction of exhaust flow through the AMECU **22**.

Continuing with FIGS. **5**A, **5**B, The AMECU **22** resides proximal to waste tanks **60**, storage tanks **61**, a power source **64** and the cabin **13** which serves as a control room.

A method for using the AMECS **10** for emissions control is described in FIG. **6**. The method includes positioning the EIB **14** over a stack **26** of an OGV **24** at step **100**. Tightening a cage around the stack at step **102**. Lowering a shroud over the cage at step **104**. Retracting the end segment **22***d* at step

106. Drawing the exhaust through the duct **19** to the AMECU **22** at step **108**. Processing the exhaust at step **110**. Releasing the processed exhaust at step **112**.

Processing the exhaust at step **110** preferably comprises the steps of pre conditioning the exhaust at step **114**, oxidizing at step **116**, reducing at step **118**, polishing at step **120**, and precipitating at step **122**.

The invention further contemplates a land based structure in place of the USB **12** for use when the OGV **24** is moored to a dock, or for control of emissions from land based equipment. The land based structure would support the same elements as the USB **12** based AMECS **10** with the exception that the tower **16**, AMECU **22**, and associated equipment would be supports on the land instead of on the USB **12**. The system may, for example, be mounted to a truck, a trailer, or a rail road car.

While the invention herein disclosed has been described by means of specific embodiments and applications thereof, numerous modifications and variations could be made thereto by those skilled in the art without departing from the scope of the invention set forth in the claims.

We claim:

1. An advanced maritime emissions control system comprising:

a bonnet configured for residing over a ship stack for capturing exhaust from the ship stack, the bonnet contractable around the ship stack to sufficiently grasp the ship stack to hold the bonnet in place over the ship stack;

an emissions control unit for processing the exhaust from the stack; and

a duct for carrying the exhaust from the bonnet to the emissions control unit.

2. The emissions control system of claim **1**, further including:

a tower; and

an articulating arm extending from the tower,

wherein the bonnet is positioned on the stack by the articulating arm.

3. The emissions control system of claim **1**, further including:

a tower; and

an articulating arm extending from the tower,

wherein the duct is supported by the articulating arm.

4. The emissions control system of claim **3**, wherein the articulating arm includes segments.

5. The emissions control system of claim **4**, wherein the articulating arm includes pivoting joints between the segments.

6. The emissions control system of claim **4**, wherein the segments include an end segment connectable to the bonnet for placing the bonnet on the stack, and wherein the end segment is disconnectable from the bonnet.

7. The emissions control system of claim **1**, wherein the bonnet is selectable from a multiplicity of shaped bonnets.

8. The emissions control system of claim **1**, wherein the bonnet comprises a top, a cage extending from the top, and a shroud lowerable over the cage.

9. The emissions control system of claim **8**, wherein the cage comprises downwardly reaching curved ribs.

10. The emissions control system of claim **9**, wherein the ribs comprise between eight and twenty four ribs.

11. The emissions control system of claim **10**, wherein the tubes comprise about sixteen ribs.

12. The emissions control system of claim **9**, wherein shroud cords attach to a lower edge of the shroud and wherein pulling on the shroud cords lowers the shroud over the tubes.

13. The emissions control system of claim **9**, wherein the ribs comprise tubes, and wherein the tubes include pulleys near a lower end of each tube, and wherein the shroud cords loop around the pulleys, wherein the shroud cords are pulled upward through the tubes to lower the shroud.

14. The emissions control system of claim **1**, wherein the emissions control unit includes a Pre Conditioning Chamber (PCC) quench vessel.

15. The emissions control system of claim **1**, wherein the emissions control unit includes an oxidation column.

16. The emissions control system of claim **1**, wherein the emissions control unit includes a reduction column.

17. The emissions control system of claim **1**, wherein the emissions control unit includes a caustic column.

18. The emissions control system of claim **1**, wherein the emissions control unit includes a wet electrostatic precipitation system.

19. A method for emissions control, the method comprising:

securing a bonnet over a stack of an Ocean Going Vessel (OGV) to capture exhaust;

drawing the exhaust captured by the bonnet through a duct to an emissions control unit; and

processing the exhaust by the emissions control unit.

20. The method of claim **19**, wherein the bonnet includes a cage and a shroud, and wherein securing the bonnet over the stack comprises:

positioning the cage over a stack;

tightening the cage around the stack; and

lowering the shroud over the cage.

21. The method of claim **19**, wherein processing the exhaust by the emissions control system comprises:

processing the exhaust using a Pre Conditioning Chamber (PCC) quench vessel;

processing the exhaust using an oxidation column;

processing the exhaust using a reduction column;

processing the exhaust using a caustic (or polishing) column; and

processing the exhaust using a wet electrostatic precipitation system.

22. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end;

a shroud on the outward side for enclosing the frame;

a belt attached to the inward side near the downward end; and

means for tightening the downward end around the stack,

wherein the bonnet is one of several bonnets of different sizes and shapes suitable to cooperating with Ocean Going Vessel (OGV) stacks of different sizes and shapes.

23. The bonnet of claim **22**, wherein the several bonnets comprise four bonnets of different sizes and shapes.

24. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end;

wherein the frame comprises springy downwardly extending ribs.

25. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end,

wherein the belt is made from a foam material to provide an air seal between the shroud and the stack, and to retain the bonnet in place on the stack, when the downward end of the frame is tightened around the stack.

26. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end,

wherein the belt is between six inches and fourteen inches thick and between ten inches to fourteen inches high.

27. The bonnet of claim **26**, wherein the belt is approximately ten inches thick and approximately twelve inches high.

28. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end,

a capture ring assembly at the frame upward end, the capture ring including an upward facing opening with a self-aligning locking mechanism for cooperation with an articulating arm.

29. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame;

a belt attached to the inward side near the downward end; and

a camera and laser guided positioning system, wherein video from the camera is provided to an operator to use in positioning the bonnet over the stack, and wherein when the bonnet is in position over the stack, the laser guided positioning system automatically guides the bonnet into position around the stack.

30. The bonnet of claim **24**, wherein the means for tightening the downward end around the stack comprises a cord running around the outside of the frame near the downward end of the frame, and wherein drawing the cord tightens the downward end of the frame around the stack.

31. The bonnet of claim **30**, further including a constant-torque motor which when activated, tightens the cord thereby tightening the belt and providing consent pressure between the belt and the stack.

32. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end,

wherein the shroud is lowerable over the frame, and raisable to a position at the upward end of the frame.

33. The bonnet of claim **32**, wherein the shroud is lowerable and raisable using shroud cords attached to a lower edge of the shroud, wherein the shroud cords loop down outside the frame from the upward end of the frame, around pulleys near the downward end of the frame, and back to the upward end of the frame.

34. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end,

wherein the bonnet includes at least one pressure sensor which provides a pressure measurement to regulate the speed of a blower assembly to maintain a constant negative pressure within the intake duct.

35. A bonnet for capturing exhaust from a stack, the bonnet comprising:

a frame having an upward end, outward side, an inward side, and a downward end which is tightenable around the stack;

a shroud on the outward side for enclosing the frame; and

a belt attached to the inward side near the downward end,

wherein the bonnet includes an interface for a flexible duct, and wherein the flexible duct allows relative motion between the bonnet and an emissions control unit, wherein the exhaust from the stack is drawn through the flexible duct.

* * * * *

Exhibit 3

US006185934B1

(12) **United States Patent**
Teboul

(10) **Patent No.: US 6,185,934 B1**
(45) **Date of Patent: Feb. 13, 2001**

(54) **DEVICE AND METHOD FOR FILTERING INTERNAL COMBUSTION ENGINE EXHAUST GASES AND VEHICLE EQUIPPED WITH SUCH A DEVICE**

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(*) Notice: Under 35 U.S.C. 154(b), the term of this patent shall be extended for 0 days.

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PCT Pub. Date: **Dec. 31, 1997**

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(52) **U.S. Cl.** **60/297**; 60/289; 60/298; 60/308; 60/319; 60/311; 55/385.3; 55/DIG. 30; 96/58; 96/60; 95/69; 95/70

(58) **Field of Search** .... 60/297, 311, 319, 60/317, 308, 289, 290, 298; 55/385.3, 385.1, DIG. 39, DIG. 30, 302; 96/57, 58, 60; 95/69, 70, 78

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,228,755		1/1966	Lottinville .	
3,417,549		12/1968	Leosis .	
3,503,188		3/1970	Gardner .	
4,020,915		5/1977	Darnell et al. .	
4,338,784		7/1982	Liu et al. .	
4,706,455		11/1987	Johnsson .	
5,012,641		5/1991	Travalee .	
5,085,049	*	2/1992	Rim et al.	60/274
5,492,677	*	2/1996	Yoshikawa	422/174
5,540,716	*	7/1996	Yamamoto	96/67
5,698,012	*	12/1997	Yoshikawa	96/47

FOREIGN PATENT DOCUMENTS

316 252	11/1919	(DE) .
32 35 953	3/1984	(DE) .
0 346 803	12/1989	(EP) .
792603	4/1958	(GB) .
923431	4/1963	(GB) .
2218354	11/1989	(GB) .

OTHER PUBLICATIONS

Japanese Abstract No. 04–297341, vol. 017, No. 106 (M–1375), Mar. 4, 1993.

* cited by examiner

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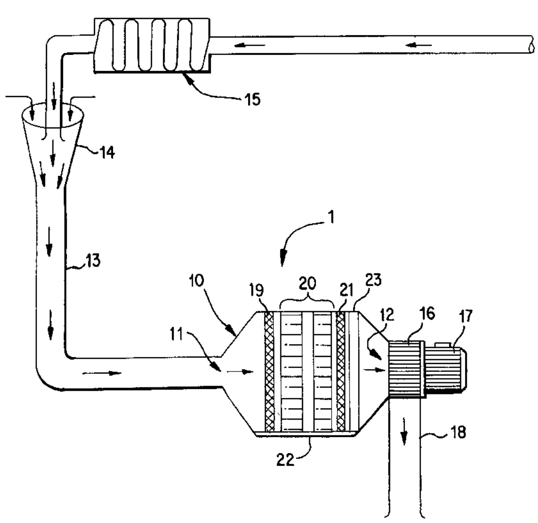
(57) **ABSTRACT**

The invention discloses a device for filtering internal combustion engine exhaust gases, comprising an electrostatic filtering chamber equipped with electrostatic filtering means, a line for supplying gases into the chamber, in fluid communication with an inlet of the chamber, at one of the ends of the supply line, the other end of the supply line being provided with an opening having an inlet orifice adapted to allow the penetration of the exhaust gases and of a flow of ambient air for cooling the exhaust gases. In this device, the means for drawing the exhaust gases and the air flow are mounted downstream of an outlet of the chamber, to allow the mixture of air and gases to pass into the said chamber and reject the filtered gases into the environment and a filter for coarse solid particles and droplets derived from the mixture is mounted in the chamber, upstream of the electrostatic filtering means.

27 Claims, 2 Drawing Sheets



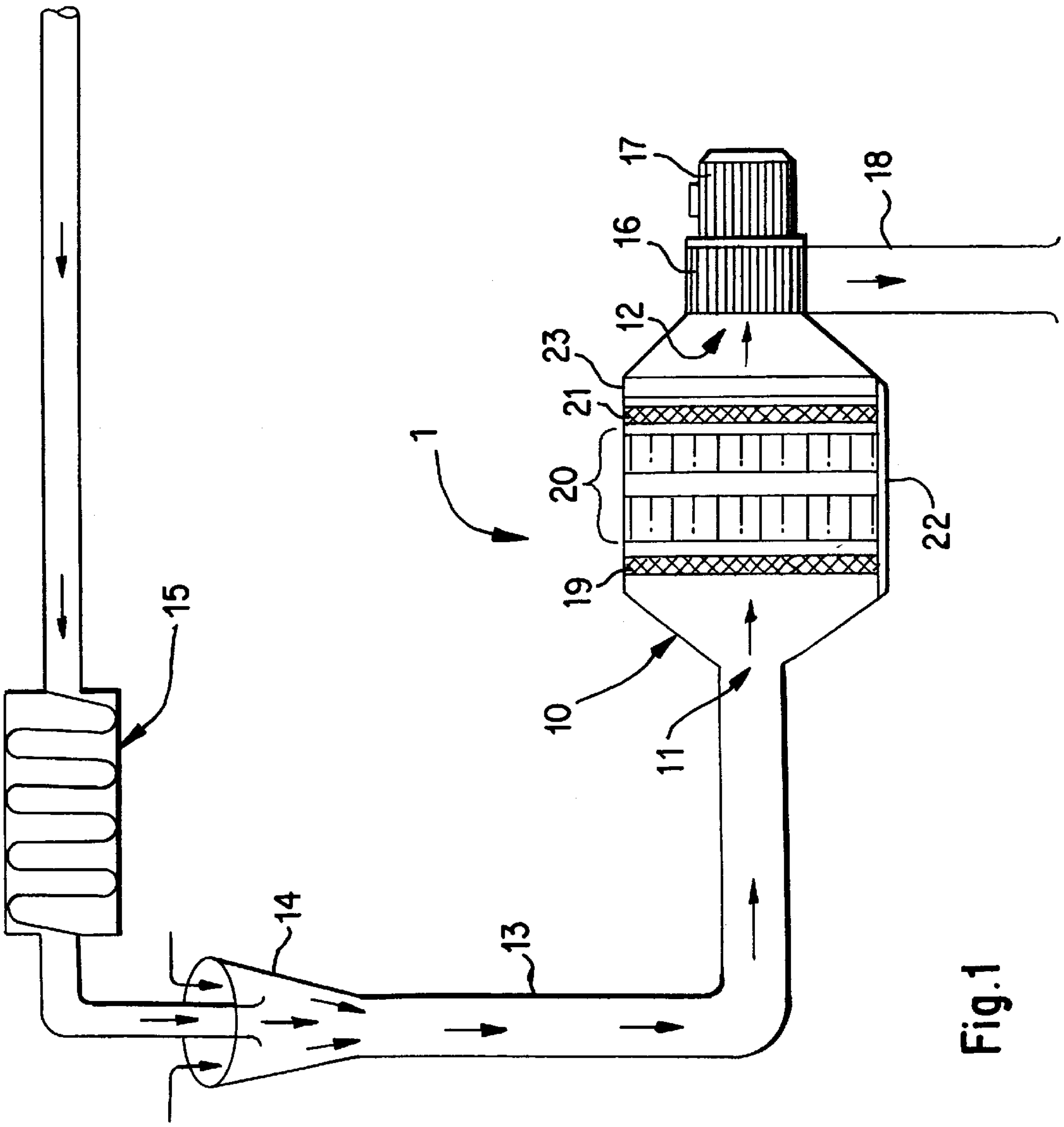


Fig.1

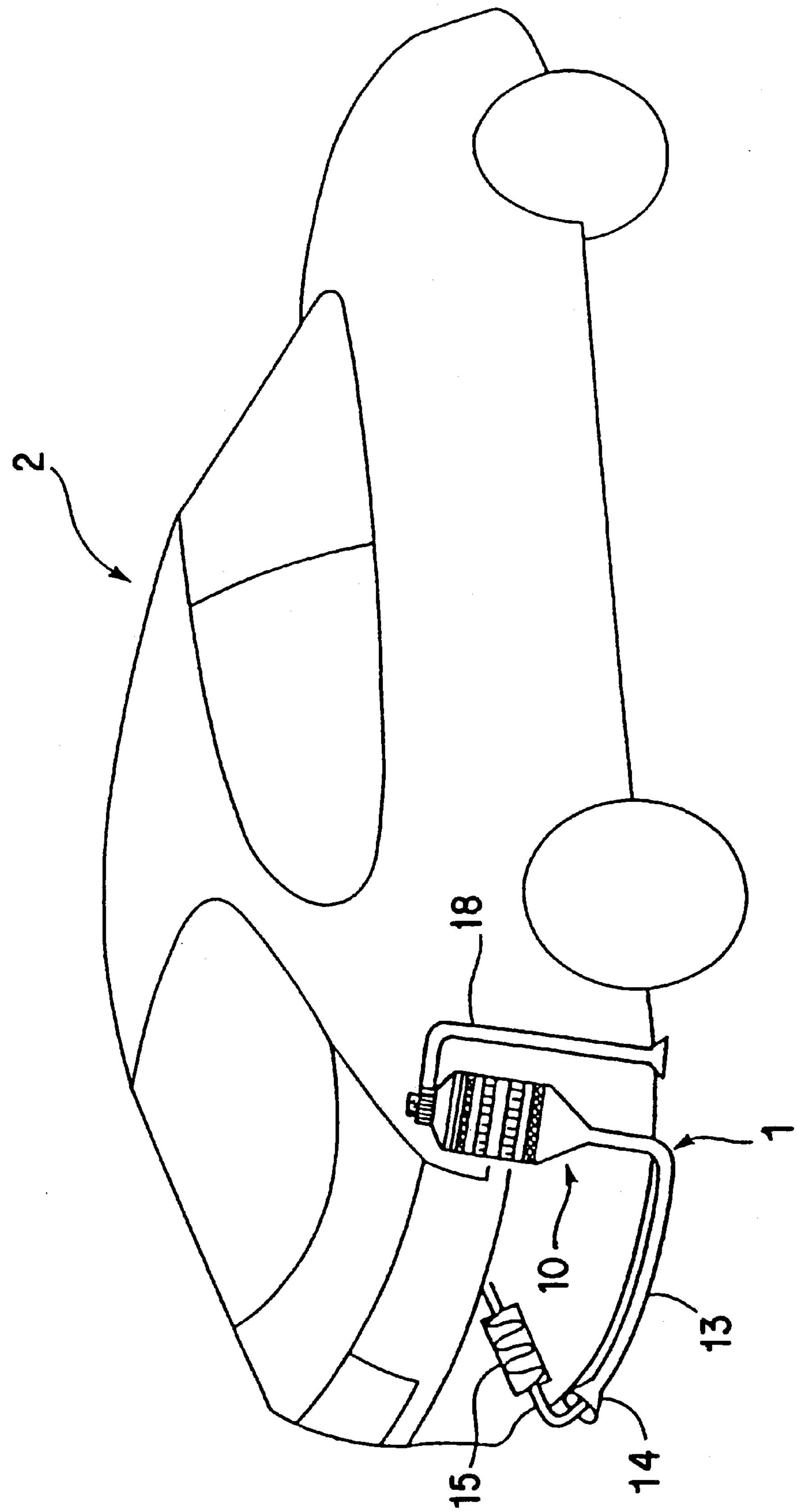


Fig. 2

DEVICE AND METHOD FOR FILTERING INTERNAL COMBUSTION ENGINE EXHAUST GASES AND VEHICLE EQUIPPED WITH SUCH A DEVICE

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to the elimination of polluting components, or of solid, liquid or gaseous impurities, from the exhaust gasses of an internal combustion engine.

A particular, but not exclusive, application is the purification of the exhaust gasses of a diesel engine.

Very many methods and devices for filtering internal combustion engine exhaust gasses have been proposed in the past.

In particular, there is known from the document GB-A-923 431, a method of eliminating solid, liquid and gaseous impurities from a flow of hot gasses in which the latter are conveyed and which comprises steps consisting of adding cool and clean air to the gasses in such a quantity and in such conditions that the flow of gasses is cooled down to a temperature below the point of condensation of that component from among the gaseous impurities that has the lowest boiling point, which means that the individual components forming the gaseous impurities condense successively and form droplets which are deposited on the liquid and solid impurities which are also contained in the flow of gas thus forming larger-sized particles. The liquid and solid particles thus obtained are then separated from the flow of gasses in a separating chamber.

In an application to an internal combustion engine, before the addition of the flow of cool and clean air, the flow of hot gasses is previously circulated in a heat exchanger in order to cool it and the separating chamber consists of an electrofilter.

There is also known, from the document EP-A-0 346 803, a method for continuously eliminating the soot and condensable volatile components from the exhaust gasses of a diesel engine, in which the hot exhaust gasses from the diesel engine are made to pass alternately through two heat exchangers, the soot and the condensable volatile components of the gasses being partially deposited on the surfaces of the heat exchanger. The exhaust gasses, cooled and charged with the remainder of the soot and of the condensable components, then pass into a coarse particles separator or a ceramic filter and then, in one of the embodiments of the invention, through an electrostatic separating device. When one of the heat exchangers is partially or totally clogged by the soot and the condensable volatile components, the latter is heated up and cleaned by combustion whilst the purification of the hot gasses takes place by passing through the other heat exchanger.

Such filtering methods and devices are relatively complex and are therefore expensive and not very easy to implement.

The present invention aims to overcome these disadvantages.

In particular, the invention proposes a filtering technology which is simple and easy to implement, whilst being at least as efficient as the existing technologies. It also proposes a filtering device which is compact and adaptable to any motor vehicle.

In order to do this it proposes, in a general manner, a device for filtering internal combustion engine exhaust gasses, comprising an electrostatic filtering chamber equipped with electrostatic filtering means, a line for supplying exhaust gasses into the filtering chamber, in fluid communication with an inlet of the filtering chamber, at one of the ends of the supply line, the other end of the supply line being provided with an opening whose inlet orifice is adapted to allow the penetration of the exhaust gasses and of a flow of ambient air intended for lowering the temperature of the exhaust gasses, characterised in that intake means, intended for drawing in the exhaust gasses and the air flow are mounted downstream of an outlet of the filtering chamber and in fluid communication with this outlet, in order to allow the mixture of exhaust gasses and air to pass into the said filtering chamber and to reject the filtered gasses into the environment and in that a filter for coarse solid particles and droplets derived from the mixture is mounted in the filtering chamber, upstream of the electrostatic filtering means.

The combination of a mechanical filter, electrostatic filtering means and the drawing through these things of a mixture of hot exhaust gasses and ambient cooling air makes it possible to filter these exhaust gasses in a particularly efficient and simple manner. Furthermore, the resulting device is compact and easy to use.

More particularly, the intake means make it possible to cause a mixture of hot exhaust gasses an ambient cooling air to penetrate into the supply line and to make this mixture pass into the filtering chamber at a constant flow rate.

Furthermore, the exhaust gasses are efficiently cooled and do not therefore damage the electrostatic filtering means.

Furthermore, the mechanical filter, particularly when the latter is constituted by an impingement-type filter, makes it possible to obtain a substantially constant pressure over the whole of the intake area of the electrostatic filtering means.

Preferably, another filter for solid particles and droplets is mounted downstream of the electrostatic filtering means, in the filtering chamber. Thus, the processing of the exhaust gasses in the electrostatic filtering means takes place in the whole of useful volume of these means, with no dead volume which could result in load loss phenomena.

Also preferably, an active carbon filter is mounted in the filtration chamber, downstream of the said other filter.

In order to prevent back-flow and turbulence phenomena, the opening of the exhaust gasses supply line comprises a conical nozzle whose wall is preferably pierced with holes.

In a preferred embodiment, the filtering means comprise two or more filtering stages.

The present invention also proposes a method of filtering the exhaust gasses of an internal combustion engine consisting in cooling the exhaust gasses by the addition of ambient air; in filtering these exhaust gasses in a filtering chamber equipped with electrostatic filtering means; characterised in that it consists in drawing the exhaust gasses and the ambient air flow through the filtering chamber and in filtering the mixture of exhaust gasses and ambient air by means of a filter for coarse solid particles and droplets, placed upstream of the electrostatic filtering means.

Advantageously, there is also filtered the mixture of exhaust gas and ambient air coming from the electrostatic filtering means, by means of another filter for solid particles and droplets.

Preferably, there is also filtered the mixture of exhaust gasses and ambient air coming from the other filter by means of an active carbon filter.

Finally, the present invention proposes a motor vehicle equipped with a filtering device such as defined above.

The supply line can be connected to the outlet of the exhaust silencer box or directly to the outlet of the exhaust

manifold of the internal combustion engine and comprises means adapted to receive the corresponding outlet.

Furthermore, the filtering device can be installed in the boot or in the engine compartment of the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

Other purposes, characteristics and advantages of the present invention will emerge from the following description, given with reference to the accompanying drawings in which:

FIG. **1** is a basic diagram of a filtering device according one embodiment of the present invention, and

FIG. **2** is a diagram illustrating a motor vehicle equipped with the device of FIG. **1**.

DETAILED DESCRIPTION OF THE DRAWINGS

The device **1** for filtering internal combustion engine exhaust gasses shown in FIGS. **1** and **2** comprises a filtering chamber **10** having an inlet **11** and an outlet **12**.

A line **13** for supplying exhaust gasses and ambient cool or cooling air is connected, by one of its ends, to the inlet **11**. The other end of the supply line **13** is provided with an opening whose inlet orifice allows the penetration into the supply line of exhaust gasses coming from an internal combustion engine as well as the flow of ambient cooling air.

In this case, this opening consists of a conical nozzle **14** receiving the outlet orifice of an exhaust silencer box **15** of a motor vehicle **2**, as illustrated in FIG. **2**.

As can be seen again in FIG. **1**, the conical nozzle **14** is located, in its widest part, in the axis of the exhaust outlet without being attached to it and in such a way as not to obstruct it and, in its narrow part, is connected to a duct of the supply line **13**.

It will be noted here that, in other embodiments, the supply line **13** can be mounted in such a way as to absorb the exhaust gasses directly at the outlet of the exhaust manifold of the internal combustion engine.

Furthermore, in order to improve the penetration of the exhaust gasses and the flow of ambient cooling air into the supply line **13** and to allow the evacuation of the exhaust gasses into the environment in the case of possible clogging of the filtering device **1**, the wall of the nozzle **14** and, if necessary, the start of the duct of the supply line **13** can be pierced with holes.

More generally, any other inlet structure can be used provided that the exhaust gasses and the flow of ambient cooling air can penetrate into the supply line **13** in an acceptable manner.

In practice, the inlet orifice of the supply line **13** has a cross-section which is twice that of the corresponding outlet orifice of the exhaust gasses and is facing either towards the rear of the vehicle, or towards the front of the vehicle.

Intake means **16**, in this case a motor turbine, are mounted downstream of the filtering chamber **10** and in fluid connection with the outlet **12**. They are driven by an electric motor **17** connected to the battery of the vehicle **2**.

The exhaust gasses filtered by the device **1** are evacuated into the atmosphere, by the intermediary of an evacuation line **18** in fluid connection with the intake means **16**.

The intake means **16** operate by depression in order to take in a quantity of ambient air, that is to say exterior to the exhaust gasses, sufficient to cool these exhaust gasses and not to damage the electrostatic filtering means of the filtering chamber **10** which will be described below. These intake means **16** furthermore operate in such a way as to have a constant flow rate all along the filtering device **1**. In practice and whilst operating, substantially the same amount of ambient air as the amount of exhaust gasses penetrate into the supply line **13**.

When the vehicle is stopped (idling conditions), the air will penetrate into the supply line **13** with a speed and in a quantity greater than the ejection of exhaust gasses.

Furthermore, the exhaust gasses are cooled, in practice, down to a temperature below 100° C. and preferably down to a temperature of less than or equal to 80° C.

The filtering chamber **10** comprises, after the inlet **11**, a filter for coarse solid particles (small and medium grain sizes) and droplets, as well as a filter comprising a metal casing and several layers of very fine meshes, or an impingement-type filter.

The electrostatic filtering means **20**, mentioned above, are, in this case, two-stage filtering means in order to obtain particularly effective filtering.

More precisely, they comprise:

an ionising section or a two-stage ioniser which makes it possible, by maintaining an electrical field, to electrostatically charge particles of the order of one hundredth of a micron;

a double-section collector cell with a large accumulation capacity consisting of plates with alternating positive and negative signs and capable of separating and retaining the micro-particles coming from the ionising section.

These electrostatic filtering means **20** produce voltages of the order of several thousand volts, by means of a power supply module (not shown) connected to the battery of the motor vehicle **2**.

Furthermore, a second filter **21**, of the same type as the filter **19**, is mounted in the filtering chamber **10** downstream of the electrostatic filtering means **20**.

The metal filter **21** intervenes principally when the electrostatic filtering means **20** are saturated or, for example, when an accumulation of solid particles detaches from the plates of the collector cell or capture cell and is carried by the flow of exhaust gas and air. It also has safety functions because it is installed upstream of an active carbon filter **23** described below.

In this respect, it will be noted that the filter **19** guarantees that the mixture penetrates over the whole of the inlet area of the electrostatic filtering means **20** with a constant pressure, whilst the filter **21** makes it possible to guarantee that the electrostatic filtering is carried out over the whole of the volume of the electrostatic filtering means **20**. In other words, the use of these two filters **19** and **21** eliminates the harmful effects of load losses resulting from the narrowings at the inlet **11** and the outlet **12** of the filtering chamber **10**.

A residues container **22** is mounted on the filtering chamber **10** in order to retrieve the impurities retained by the filters **19** and **21** and by the electrostatic filtering means **20**.

Finally, an active carbon filter **23** is mounted in the filtering chamber **10**, between the filter **21** and the outlet **12**. This filter is intended to carry out a finishing filtering by gas adsorption, in particular the adsorption of stinking gasses which are not adsorbed by the solid particles of the exhaust gasses.

The filtering chamber **10** is of course made in such a way that it can be accessed in order to be able to clean the filters, by washing, or to be able to change the filters.

As shown in FIG. **2**, the filtering device **1** is installed in the boot of the motor vehicle **2** using assembly means which are not shown.

Thanks to such a device, the exhaust gasses are cooled in an efficient manner before their entry into the filtering chamber **10**, these gasses generally having a temperature of more than 400° C. before cooling.

In the case, for example, of a diesel engine, the filter **19** particularly retains carbonaceous particles, inorganic salts and other coarse dusts together with oily mists and emulsions contained in the exhaust gasses, and also water droplets coming from the outside ambient air and other diesel fuel emanations.

In this respect it will be noted that the filtering device **1** of the present invention filters not only the exhaust gasses of the motor vehicle **2** on which it is fitted, but also the ambient air loaded with polluting emissions.

In particular, thanks to its structure, this device is efficient, at low speeds and at high speeds, from the time of starting to the time of stopping the internal combustion engine of any motor vehicle whatsoever (car, boat, . . .), without choking the engine.

The filtering device of the present invention also proves particularly advantageous in the case of petrol engines, in particular for the filtering out of lead particles contained in their exhaust gasses.

The present application is of course in no way limited to the embodiment which has been chosen and represented, but covers any variant within the scope of those skilled in the art.

In particular, the intake means **16** could be driven by the internal combustion engine, by the intermediary of a transmission belt. They could also consist of a motor-driven centrifugal fan or an extractor instead and in place of the motor-turbine.

It is also possible to provide an electrical circuit provided with an indicator lamp, intended to indicate the saturation of the electrostatic filtering means. A similar circuit can be provided to indicate the saturation of the active carbon filter **23**.

The filter **21** can also be different from the filter **19** and can comprise, in particular, nets with a finer mesh. A filter, such as the filter **19** or **21**, could also be provided between the two stages of the electrostatic filtering means **20**. In this respect it will be noted that the dry filtering device **1** of the present invention can be adapted, by the choice of filters, to any internal combustion engine, guaranteeing that the major part of the polluting substances in the exhaust gasses are retained by the device. Furthermore, a combination of an impingement-type filter and another filter can be provided instead and in place of the single filter **19**.

Furthermore, a mixer plate can be fitted between the inlet **11** and the filter **19**.

Furthermore, the structure and the disposition of the constituent elements of the electrostatic filtering means can be different (several filtering cells side by side, number of stages chosen according to the cubic capacity of the engine . . .).

Finally, the intake means could be coupled to the acceleration system of the vehicle in order to regulate the intake of ambient air.

What is claimed is:

1. A device (**1**) for filtering internal combustion engine exhaust gasses, comprising an electrostatic filtering chamber (**10**) equipped with electrostatic filtering means (**20**), a line (**13**) for supplying exhaust gasses into the filtering chamber (**10**), in fluid communication with a inlet (**11**) of the filtering chamber (**10**), at one of the ends of the supply line (**13**), the other end of the supply line (**13**) having an inlet adapted to allow the penetration of the exhaust gasses from an outlet of one of an exhaust silencer box and an exhaust manifold connectable to the internal combustion engine, while allowing the penetration of a flow of ambient air that does not come off the exhaust silencer box or exhaust manifold and which is intended for lowering the temperature of the exhaust gasses, wherein an intake unit (**16**), intended for drawing in the exhaust gasses and the air flow is mounted downstream of an outlet (**12**) of the filtering chamber (**10**) and in fluid communication with this outlet (**12**), in order to allow the mixture of exhaust gasses and air to pass into the said filtering chamber (**10**) and to reject the filtered gasses into the environment, and further wherein a filter (**19**) for coarse solid particles and droplets derived from the mixture is mounted in the filtering chamber (**10**), upstream of the electrostatic filtering means (**20**).

2. Device according to claim **1**, wherein the filter is an impingement-type filter.

3. Device according to claim **2**, wherein another filter (**21**) for coarse solid particles and droplets is mounted downstream of the electrostatic filtering means, in the filtering chamber (**10**).

4. Filtering device according to claim **3**, wherein said other filter is an impingement-type filter.

5. Filtering device according to claim **4**, wherein an active carbon filter (**23**) is mounted in the filtering chamber (**10**) downstream of the said other filter (**21**).

6. Device according to claim **1**, wherein another filter (**21**) for coarse solid particles and droplets is mounted downstream of the electrostatic filtering means, in the filtering chamber (**10**).

7. Filtering device according to claim **6**, wherein the said other filter is an impingement-type filter.

8. Filtering device according to claim **7**, wherein an active carbon filter (**23**) is mounted in the filtering chamber (**10**) downstream of the said other filter (**21**).

9. Filtering device according to claim **6**, characterised in that an active carbon filter (**23**) is mounted in the filtering chamber (**10**) downstream of the said other filter (**21**).

10. Filtering device according to claim **1** wherein the electrostatic filtering means comprise two or more filtering stages.

11. Device according to claim **1**, wherein the inlet comprises a conical nozzle whose widest part is intended to receive the outlet of the one of the exhaust silencer box and the exhaust manifold.

12. Filtering device according to claim **11**, wherein a wall of the conical nozzle is pierced with holes.

13. Filtering device according to claim **1**, wherein the exhaust gasses are cooled down to a temperature of less than 100° C. and preferably down to a temperature of less than or equal to 80° C.

14. Filtering device according to claim **1**, wherein it comprises means of fitting to a motor vehicle.

15. Motor vehicle (**2**) equipped with a filtering device (**1**) according to claim **1**.

16. Method of filtering the exhaust gasses of an internal combustion engine, the method comprising the acts of:

providing an exhaust gas outlet from one of an exhaust silencer box and an exhaust manifold connectible to the internal combustion engine;

receiving the exhaust gasses from the outlet of said one of the exhaust silencer box and the exhaust manifold, while simultaneously receiving an ambient air flow that does not come off the exhaust silencer box or exhaust manifold, said ambient air flow lowering a temperature of the received exhaust gasses;

drawing the exhaust gasses and the ambient air flow through a filtering chamber equipped with an electrostatic filter; and

filtering the mixture of the exhaust gasses and ambient air flow via a filter for coarse solid particles and droplets, placed upstream of the electrostatic filter.

17. Method according to claim **16**, wherein the mixture of exhaust gasses and ambient air coming from the electro static filter is also filtered by another filter for coarse solid particles and droplets.

18. Method according to claim **17**, wherein the mixture of exhaust gasses and ambient air coming from the other filter is also filtered by an active carbon filter.

19. A motor vehicle, comprising:

an internal combustion engine which outputs exhaust gasses; and

a device for filtering said exhaust gasses, said device comprising:

an electrostatic filtering chamber **(10)** equipped with electrostatic filtering means **(20)**, a line **(13)** for supplying exhaust gasses into the filtering chamber **(10)**, in fluid communication with a inlet **(11)** of the filtering chamber **(10)**, at one of the ends of the supply line **(13)**, the other end of the supply line **(13)** having an inlet adapted to allow the penetration of the exhaust gasses from an outlet of one of an exhaust silencer box and an exhaust manifold connectable to the internal combustion engine, while allowing the penetration of a flow of ambient air that does not come off the exhaust silencer box or exhaust manifold and which is intended for lowering the temperature of the exhaust gasses, wherein an intake unit **(16)**, intended for drawing in the exhaust gasses and the air flow is mounted downstream of an outlet **(12)** of the filtering chamber **(10)** and in fluid communication with this outlet **(12)**, in order to allow the mixture of exhaust gasses and air to pass into the said filtering chamber **(10)** and to reject the filtered gasses into the environment, and further wherein a filter **(19)** for coarse solid particles and droplets derived from the mixture is mounted in the filtering chamber **(10)**, upstream of the electrostatic filtering means **(20)**.

20. A motor vehicle according to claim **19**, wherein the filter is an impingement-type filter.

21. A motor vehicle according to claim **19**, wherein another filter **(21)** for coarse solid particles and droplets is mounted downstream of the electrostatic filtering means, in the filtering chamber **(10)**.

22. A motor vehicle according to claim **21**, wherein the said other filter is an impingement-type filter.

23. A motor vehicle according to claim **21**, wherein an active carbon filter **(23)** is mounted in the filtering chamber **(10)** downstream of the said other filter **(21)**.

24. A motor vehicle according to claim **19**, wherein the electrostatic filtering means comprise two or more filtering stages.

25. A motor vehicle according to claim **19**, wherein the inlet comprises a conical nozzle whose widest part is intended to receive the outlet of the one of the exhaust silencer box and the exhaust manifold.

26. A motor vehicle according to claim **25**, wherein the a wall of the conical nozzle is pierced with holes.

27. Filtering device according to claim **19**, wherein the exhaust gasses are cooled down to a temperature of less than 100° C. and preferably down to a temperature of less than or equal to 80° C.

* * * * *

Exhibit 4

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Attorneys for Plaintiff
CLEAN AIR ENGINEERING-MARITIME, INC.

UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

WESTERN DIVISION

CLEAN AIR ENGINEERING-MARITIME, INC., a California corporation, Plaintiff, vs. ADVANCED CLEANUP TECHNOLOGIES, INC., and ADVANCED ENVIORNMENTAL [sic] GROUP, LLC, a California corporation, Defendants.	Case No. 2:12-cv-08669-JAK-VBK **EXPERT REPORT OF MARKO PRINCEVAC, PH.D. RE ANTICIPATION OF CLAIM 19 OF U.S. PATENT NO. 7,258,710**

EXPERT REPORT OF MARKO PRINCEVAC, PH.D.

I, Marko Princevac, Ph.D., declare as follows:

I. ENGAGEMENT

1. I am an Associate Professor in Mechanical Engineering at the Bourns College of Engineering at the University of California, Riverside. I have been asked by Plaintiff and Counter-Claim Defendant Clean Air Engineering-Maritime Inc. ("CAEMI") to provide expert opinions and testimony regarding the anticipation of claim 19 of U.S. Patent No. 7,258,710 ("the '710 patent"). I have personal knowledge of the facts stated herein and could and would testify competently thereto if called upon to do so.

2. This report sets forth my opinions and the bases for my opinions regarding the validity of the '710 patent. My opinions are based on reviewing the '710 patent, U.S. Patent No. 6,185,934 ("Teboul"), my knowledge of the relevant technology, and my understanding of the applicable principles of patent law, as explained to me by CAEMI's attorneys and as set forth in Section IV below. With respect to claim construction, I have considered the claim construction order dated December 18, 2013 of the United States District Court for the Central District of California in this case (hereinafter "Claim Construction Ruling"). I have reviewed the documents noted in Exhibit A. This study is ongoing, and I may supplement or amend these opinions based on the results of further analysis and in response to positions taken by Defendant and Counter-Claim Plaintiff Advanced Cleanup Technologies, Inc. and Advanced Enviornmental [sic] Group, LLC (collectively, "ACTI").

3. I am being compensated for my time spent in connection with this case at the rate of $200 per hour. Except for my consulting duties, I have no financial stake in this litigation, and my compensation is not contingent upon the outcome of this litigation.

II. SUMMARY OF OPINIONS

4. Based on my analysis of the '710 patent and Teboul and the materials identified above, as well as the legal principles explained to me, it is my opinion that claim 19 of the '710 patent is anticipated by clear and convincing evidence. My opinions are set forth in more detail below.

III. QUALIFICATIONS

5. I have studied and worked extensively in the fields of air pollution, environmental engineering, naval architecture, and mechanical engineering for the past seventeen years. I have extensive knowledge of diesel and internal combustion engines, their emissions, and control of those emissions, from cars, boats, and other sources.

6. The focus of my research has been in fundamental and applied fluid mechanics – in particular, the application of fundamental turbulence concepts to studies in environmental flows. In this area, I identify physical phenomena and build physical (laboratory) models that can successfully explain complex field observations or a part thereof. I also have experience developing idealized theoretical models to explain fluid dynamic processes. My approach has been to cross-fertilize field measurements with carefully designed laboratory experiments and simple theoretical analysis.

7. My early research focused on "engineering flows," specifically ships' propulsion and resistance. This research resulted in several polynomial models for the estimation of the power and resistance for the specific type of semi-displacement hull forms. In graduate school I focused my research on thermally driven environmental flows, motivated by tremendous air quality problems that are occurring in cities located in areas with complex terrain.

8. I currently focus on field experimental research on urban flows, specifically on urban dispersion (pollutants or toxic releases, industrial disasters or terrorist attacks) and parameterizations of turbulence within urban canyons.

9. I teach classes dealing with air pollution. The class Environmental Impacts of Energy Production & Conversion (ME136) is part of the Energy and Environment focus area within the Department of Mechanical Engineering. This class covers thermodynamics, heat transfer, and fluid mechanics as applied to the examination of the environmental impacts of energy production and conversion. Topics include pollution associated with fossil fuel combustion, environmental impacts of energy use, turbulent transport of pollutants, and principles used in the design of pollution control equipment. Many of my recent projects and field experiments involve air pollution and the study of emissions and how they travel and disperse in the atmosphere. I recently completed a project that modeled transportation emissions from cars, and I have worked on other projects involving distributed generation sources that involve the study of emissions from internal combustion engines and generators.

10. I am also involved in marine engineering. As an undergraduate, I majored in naval architecture, where I learned about boat building, including managing boat exhaust. I currently own a sailboat with a diesel engine, which I sail several times a month on average. I recently completed a project involving the impact of hydrogen injection in marine diesel engines for the California Air Resources Board (CARB). This project resulted in an article I submitted to the journal *Fuel* in 2011 entitled, "Effect of Hydrogen Injection on Emissions from a Two-Stroke Marine Diesel Engine."

11. I have tested tugboat emissions in the Port of Los Angeles. This testing involved hybrid (diesel-electric) internal combustion engines for the

tugboats. I am on the doctoral qualifying committee for two doctoral candidates who are using this data for their Ph.D. work.

12. I am a member of The Society of Naval Architects and Marine Engineers (SNAME), The American Meteorological Society (AMS), and The American Society of Mechanical Engineers (ASME).

13. I received a B.Sc. degree in Mechanical Engineering and Naval Architecture from the University of Belgrade in Serbia in 1997 and a Ph.D. in Mechanical Engineering from Arizona State University in 2003.

14. After one year of postdoctoral research after receiving my Ph.D., I began teaching at UC Riverside in 2004 and have been teaching there for the last ten years, gaining tenure in 2010.

15. My *curriculum vitae* and list of publications are attached as Exhibit B. I have not testified as an expert at trial or by deposition.

IV. LEGAL STANDARDS

A. Burden of Proof

16. Attorneys for CAEMI have informed me of a number of legal principles regarding patent validity that I have taken into account in forming my opinions. As an initial matter, it is my understanding that patent applications are reviewed and approved by examiners trained in the technical field of the invention. Because of this examination process, an issued patent is presumed to be valid over the prior art. Accordingly, there is a burden on a party challenging the validity of a patent – that party must prove that a patent is invalid by clear and convincing evidence. I further understand that this means that the party challenging the validity of a patent must demonstrate an abiding conviction that the truth of the factual contentions is highly probable.

17. Because of the presumption of validity of United States patents, I understand the burden of proving invalidity of the ’710 patent is on CAEMI.

B. Anticipation

18. It has been explained to me that a claim may be invalidated by "anticipation."

19. It has been explained to me that under the doctrine of anticipation in effect when the '710 patent issued (under 35 U.S.C. § 102), a claim may be anticipated if it is not new – that is, if there is a single prior art reference that discloses, explicitly or inherently, all of the limitations of the patent claim.

V. CLAIM 19 OF U.S. PATENT NO. 7,258,710 IS ANTICIPATED

A. Level of Ordinary Skill in the Art

20. Based on my years as a professor of graduate and undergraduate students, and as an advisor to Master's and Ph.D. candidates in Mechanical Engineering, I believe that the definition of a person of ordinary skill in the art relating to the '710 patent is one who would have at least a B.S. degree in mechanical or environmental engineering, or an equivalent formal education, and would have at least two years of work or research experience involving diesel emissions or related areas. One of ordinary skill in the art could also have a Master's degree in one of these same fields and at least one year of relevant work or research experience.

B. Summary of the '710 Patent

21. The '710 patent (attached as Exhibit C) is directed to a maritime emissions control system. The emissions comprise pollutants in exhaust produced when an engine burns diesel fuel.

22. The '710 patent was filed April 29, 2004 and does not claim priority from any other application or publication.

23. As shown in ’710 patent Fig. 2A (right), two ships (12, 24) are positioned next to one another in the sea water. One ship (12 – the “Unpowered Seagoing Barge” or “USB”) carries an “emissions control unit” (not shown) to process exhaust received from the second ship (24 – the “Ocean Going Vessel” or “OGV”), coming into port.

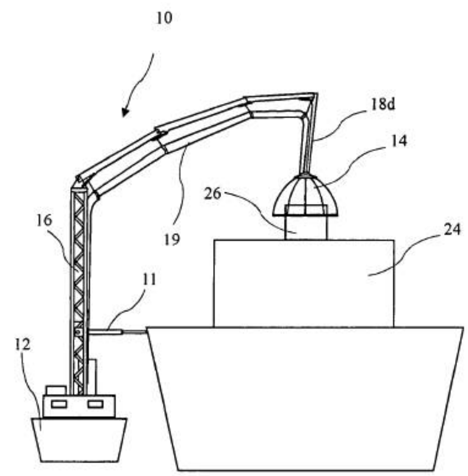


FIG. 2A

‘710 Patent Fig. 2A

24. The OGV emits the exhaust through a stack (26), and a bonnet (14) captures the exhaust which is drawn to the emissions control unit on the USB through the duct (19).

C. Claim 19 of the ’710 Patent

25. This declaration is directed to claim 19 of the ’710 patent. Claim 19 provides:

19. A method for emissions control, the method comprising:

securing a bonnet over a stack of an Ocean Going Vessel (OGV) to capture exhaust;

drawing the exhaust captured by the bonnet through a duct to an emissions control unit; and

processing the exhaust by the emissions control unit.

D. Claim Construction

26. I understand the following claim construction, which is compiled from the Court’s Claim Construction Ruling, dated December 18, 2013, applies to claim 19 as follows:

U.S. Patent No. 7,258,710	
Disputed Claim Term	**Construction**
bonnet	[the term does not require construction]
stack	a structure extending from the ship that emits exhaust
securing a bonnet over a stack	[the term does not require construction]

E. Summary of the Bases of Opinions

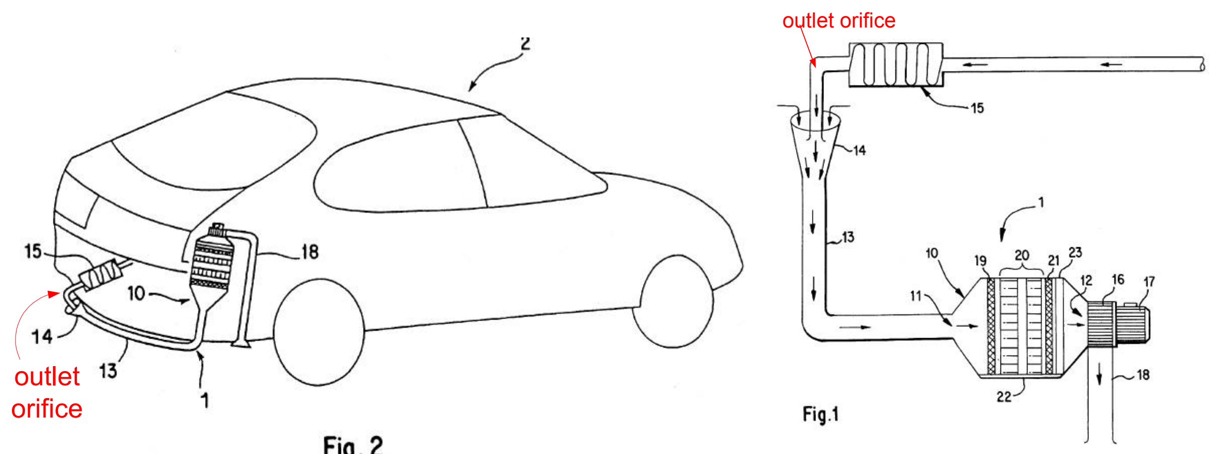
27. I have reviewed the ’710 patent and U.S. Patent No. 6,185,934. I find that U.S. Patent No. 6,185,934 anticipates claim 19 of the ’710 patent.

F. Summary of Teboul

28. Teboul (attached as Exhibit D) is directed to an emissions control system that can be used to process exhaust produced when a car’s, boat’s, or other motor vehicle’s engine burns diesel fuel.

29. Teboul issued on February 13, 2001.

30. As shown in Teboul Figs. 1 and 2 (below, annotated in red), a motor vehicle 2 is connected to an “exhaust silencer box” (*e.g.*, a muffler) 15 that has an



Teboul Figs. 2 and 1 (annotated)

outlet orifice (*e.g.*, a tailpipe) that penetrates a conical nozzle 14. Conical nozzle 14 is connected to an emissions filtering device 1, which is used to filter internal combustion engine exhaust gases that come out of the outlet orifice, via supply line 13. Emissions filtering device 1 includes filtering chamber 10 having an inlet 11

and an outlet 12. Filtering chamber 10 further includes filters 19 and 21, electrostatic filtering means 20, active carbon filter 23, and residues container 22. Filtering chamber 10 is in fluid connection with intake means 16, which may be a motor turbine and which is driven by electric motor 17.

G. Anticipation of Claim 19 of the ’710 Patent by Teboul

31. Claim 19 of the ’710 patent includes a preamble plus three limitations. Each of them is found in Teboul.

32. Like the ’710 patent, Teboul discloses a method for controlling exhaust emissions by using a conical nozzle which is secured as a bonnet over an exhaust emission structure. Like the ’710 patent, Teboul discloses that the exhaust is captured by the conical nozzle and drawn through a supply line, which is a duct, to a filtering device, which is an emissions control unit. The filtering device then processes the exhaust.

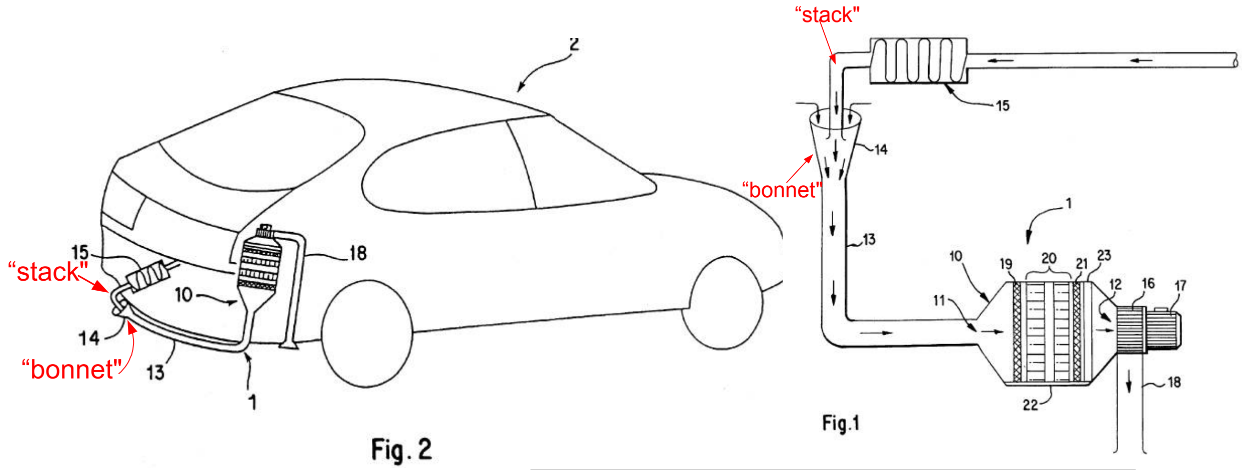
1. Preamble: “A method for emissions control, the method comprising”

33. Teboul discloses the subject matter of Claim 19’s preamble, which recites “[a] method for emissions control.” Teboul discloses methods of emissions control. Teboul is directed to “the elimination of polluting components, or of solid, liquid or gaseous impurities, from the exhaust gasses of an internal combustion engine,” including a diesel engine. Teboul*,* 1:8-11. Removing impurities from exhaust gases is emissions control.

2. “securing a bonnet over a stack of an Ocean Going Vessel (OGV) to capture exhaust”

34. The Court did not construe “bonnet” other than to say that a bonnet does not require a “cage and shroud.” Claim Construction Ruling at 8. Teboul discloses a bonnet, which it describes as a “conical nozzle 14,” which is attached to

the "supply line" and captures exhaust gases. Teboul, 3:18-30. Teboul Figs. 1 and 2 are annotated below in red to indicate the "conical nozzle 14," which is a bonnet.



Teboul Figs. 2 and 1 (annotated)

35. The Court construed "stack" to mean "a structure extending from the ship that emits exhaust." Claim Construction Ruling at 8. Teboul discloses an "outlet orifice of an exhaust silencer box 15 of a motor vehicle 2," which is a stack. Teboul, 3:28-31. Alternatively, the "exhaust manifold of the internal combustion engine" is a stack. Teboul, 2:66-3:2. Teboul discloses that conical nozzle 14 (*i.e.*, the "bonnet") may be connected either to the outlet of exhaust silencer box 15 (*i.e.*, the tailpipe on a muffler) or directly to the engine exhaust manifold. *Id.*; *see also* Teboul, 3:37-40. Either the exhaust manifold or the "outlet orifice" are "stacks," because each is a "structure extending from the [vehicle and] that emits exhaust." The outlet orifice (*i.e.,* tailpipe), in particular, extends from the vehicle, as illustrated in the above annotated version of Figs. 1 and 2.

36. The Court did not construe "securing a bonnet over a stack." Claim Construction Ruling at 12. In Teboul, the bonnet is "connected" to the stack. For example:

> The supply line can be connected to the outlet of the exhaust silencer box or directly to the outlet of the exhaust manifold of the internal combustion engine and comprises means adapted to receive the corresponding outlet.

Teboul, 2:66-3:2.

37. Teboul Fig. 1 is shown on the previous page, annotated to depict the locations of the "stack" and "bonnet" and showing how they are connected such that the bonnet is secured over the stack.

38. Below, Teboul Fig. 1 is inverted to show the correspondence with Fig. 3B of the '710 patent. The bonnet (conical nozzle 14) and stack (outlet orifice) are arranged coaxially such that the bonnet is wider than and surrounds or fits over a portion of the stack. The stack extends inside a portion of the bonnet. Since conical nozzle 14 and supply line 13 are connected to the outlet orifice, and conical nozzle 14 is wider than and fits over the outlet orifice, the conical nozzle ("bonnet") is secured over the outlet orifice ("stack").

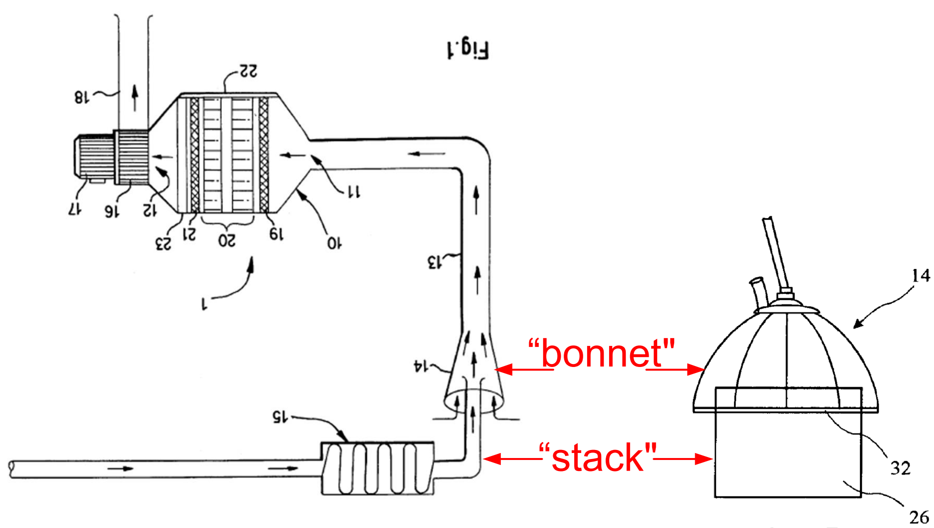


FIG. 3B

Teboul Fig. 1	'710 patent, Fig. 3B

39. Fig. 3B of the '710 patent illustrates stack 26 extending inside a portion of bonnet 14, in the same way that Teboul depicts the tailpipe extending into the conical nozzle. In both cases the "bonnet" is secured over the stack.

40. Although the figures in Teboul are directed to a car, Teboul explicitly recites that its apparatus is applicable to other types of vehicles, including marine vessels. For example, Teboul states that its apparatus "proposes a filtering device

which is compact and adaptable to ***any motor vehicle***." Teboul, 1:62-63 (emphasis added). And "[i]n particular, thanks to its structure, this device is efficient, at low speeds and at high speeds, from the time of starting to the time of stopping the internal combustion engine of ***any motor vehicle whatsoever*** (car, ***boat***, . . .), without choking the engine." *Id.*, 5:15-19 (emphasis added). Moreover, Teboul discloses that its apparatus can be used with "exhaust gasses of a diesel engine," *id.*, 1:13, and most marine engines are diesel engines. Thus Teboul discloses that its apparatus may be used with a boat, a ship, or other ocean going vessel.

41. Finally, the purpose of Teboul's conical nozzle 14 (*i.e.*, the bonnet) is to "capture exhaust." Teboul's apparatus "receive[s] the exhaust gasses from the outlet" orifice. Teboul, 6:59-60. Teboul discloses ways to optimize the capture of exhaust so that it can penetrate into supply line 13 via conical nozzle 14 and be carried to filtering device 1. For example:

> A line 13 for supplying exhaust gasses and ambient cool or cooling air is connected, by one of its ends, to the inlet 11. The other end of the supply line 13 is provided with an opening whose inlet orifice allows the penetration into the supply line of exhaust gasses coming from an internal combustion engine as well as the flow of ambient cooling air.
>
> In this case, this opening consists of a conical nozzle 14 receiving the outlet orifice of an exhaust silencer box 15 of a motor vehicle 2, as illustrated in FIG. 2.

Teboul, 3:21-31.

42. In other words, the inlet orifice of supply line 13 *is* conical nozzle 14 (*i.e.*, the bonnet). The bonnet thus "allows the penetration into the supply line of exhaust gasses." This means that the conical nozzle captures exhaust.

3. "drawing the exhaust captured by the bonnet through a duct to an emissions control unit"

43. Teboul's conical nozzle 14 (the bonnet) is an inlet orifice for supply line 13. Supply line 13 is a "duct to an emissions control unit."

44. The exhaust that is captured by the bonnet is drawn through supply line 13 (the duct):

> A line 13 for supplying exhaust gasses and ambient cool or cooling air is connected, by one of its ends, to the inlet 11. The other end of the supply line 13 is provided with an opening whose inlet orifice ***allows the penetration into the supply line of exhaust gasses*** coming from an internal combustion engine as well as the flow of ambient cooling air.

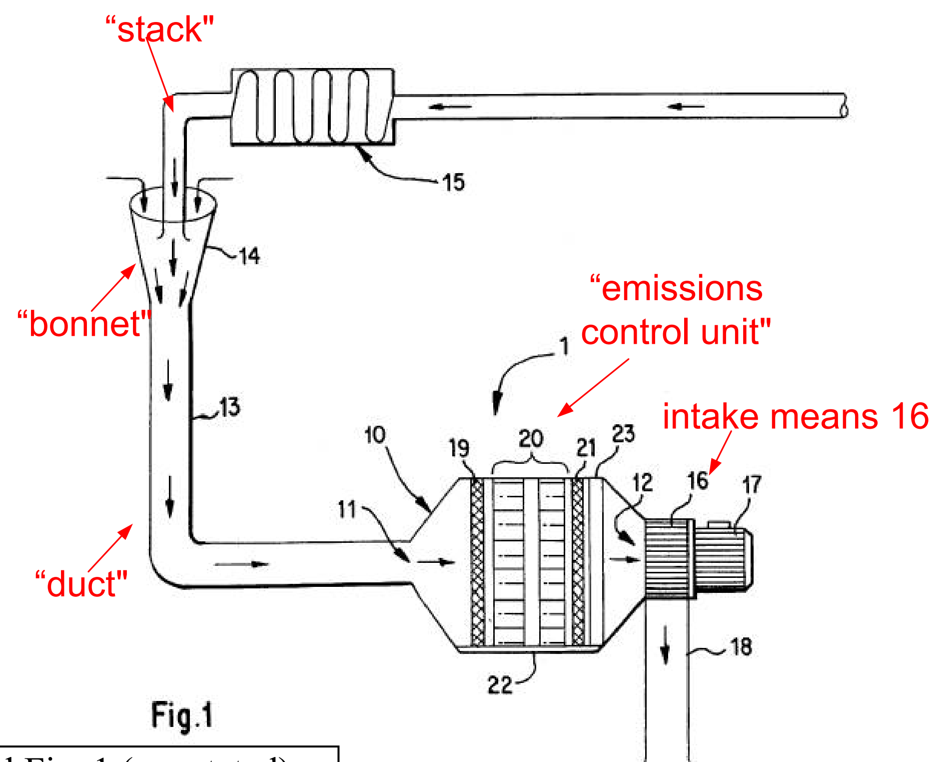
Teboul, 3:21-27 (emphasis added).

45. Teboul describes the flow of exhaust gases through the filtering means (*i.e.*, the "emissions control unit") as "drawing" the exhaust:

> The combination of a mechanical filter, electrostatic filtering means and the ***drawing*** through these things of ***a mixture of hot exhaust gasses and ambient cooling air*** makes it possible to filter these exhaust gasses in a particularly efficient and simple manner.

Teboul, 2:17-21 (emphasis added).

46. Supply line 13 (the duct) is connected to filtering device 1 (the "emissions control unit") which receives the exhaust gases. Intake means 16, a motor turbine, draws the exhaust from the engine. These features are indicated in the following annotated version of Fig. 1:



Teboul Fig. 1 (annotated)

47. Filtering device 1 is an emissions control unit because it controls the emissions of the vehicle by filtering pollutants from the exhaust. For example, filtering device 1 is described as comprising a filtering chamber 10, a "filter for coarse solid particles" and "droplets, as well as a filter comprising a metal casing and several layers of very fine meshes, or an impingement-type filter." Teboul, 4:13-17. It also comprises "electrostatic filtering means 20." Teboul, 4:17-18. The result is described as being particularly useful for "the filtering out of lead particles contained in their exhaust gasses." Teboul, 5:20-23.

48. Thus, Teboul discloses allowing the penetration into supply line 13 of exhaust gases captured by conical nozzle 14, the exhaust being drawn to emissions filtering device 1, which is "drawing the exhaust captured by the bonnet [14] through a duct [13] to an emissions control unit [1]."

4. "processing the exhaust by the emissions control unit"

49. Teboul's filtering device 1 (the "emissions control unit") performs numerous steps on the exhaust gases, each step of which processes the exhaust. Teboul refers to this as "the processing of the exhaust":

> Preferably, another filter for solid particles and droplets is mounted downstream of the electrostatic filtering means, in the filtering chamber. Thus, the ***processing of the exhaust*** gasses in the electrostatic filtering means takes place in the whole of useful volume of these means, with no dead volume which could result in load loss phenomena.

Teboul, 2:33-38 (emphasis added). Filtering device 1 includes "electrostatic filtering means 20," *id*, 4:17-18, which performs this processing of the exhaust.

50. Filtering device 1 (the "emissions control unit") includes filtering chamber 10, which includes a "filter [19] for coarse solid particles . . . and droplets, as well as a filter comprising a metal casing and several layers of very fine meshes, or an impingement-type filter." Teboul, 4:14-17. Filtering particles and droplets is "processing the exhaust." Filter 19 may be used with a diesel engine. *Id.*, 5:5-10.

A "second filter 21," the same type as filter 19, also processes the exhaust. *Id.*, 4:34-35. An "active carbon filter 23" further processes the exhaust using gas adsorption, *id.*, 4:56-61, which is also processing the exhaust. The result of the filtering in filtering device 1 is described as being particularly useful for "the filtering out of lead particles contained in their exhaust gasses." *Id.*, 5:20-23. Again, this is a form of processing the exhaust.

51. Thus, Teboul includes the limitation "processing the exhaust by the emissions control unit."

H. Conclusion

52. Based on the foregoing, Teboul discloses the preamble plus the three limitations of claim 19 of the '710 patent, thus rendering the claim anticipated.

I declare under penalty of perjury that the foregoing is true and correct.

Executed this 2nd day of April, 2014, at Riverside, California.

Marko Princevac

Marko Princevac, Ph.D.

Exhibit 5

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Attorneys for Plaintiff
CLEAN AIR ENGINEERING-MARITIME, INC.

UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

WESTERN DIVISION

CLEAN AIR ENGINEERING-MARITIME, INC., a California corporation,

Plaintiff,

vs.

ADVANCED CLEANUP TECHNOLOGIES, INC., and ADVANCED ENVIORNMENTAL [sic] GROUP, LLC, a California corporation,

Defendants.

Case No. 2:12-cv-08669-JAK-VBK

DECLARATION OF MARKO PRINCEVAC, PH.D. IN SUPPORT OF PLAINTIFF CLEAN AIR ENGINEERING-MARITIME, INC.'S MOTION FOR SUMMARY JUDGMENT

Date: June 23, 2014
Time: 8:30 a.m.
Place: Roybal 750 – 7th Floor
Judge: John A. Kronstadt

DECLARATION OF MARKO PRINCEVAC, PH.D.

I, Marko Princevac, Ph.D., declare as follows:

I. ENGAGEMENT

1. I am an Associate Professor in Mechanical Engineering at the Bourns College of Engineering at the University of California, Riverside. I have been asked by Plaintiff and Counter-Claim Defendant Clean Air Engineering-Maritime Inc. ("CAEMI") to provide expert opinions and testimony regarding the anticipation of claim 19 of U.S. Patent No. 7,258,710 ("the '710 patent"). I have personal knowledge of the facts stated herein and could and would testify competently thereto if called upon to do so.

2. This declaration sets forth my opinions and the bases for my opinions regarding the validity of the '710 patent. My opinions are based on reviewing the patent, U.S. Patent No. 6,185,934 ("Teboul"), my knowledge of the relevant technology, and my understanding of the applicable principles of patent law, as explained to me by CAEMI's attorneys and as set forth in Section IV below. With respect to claim construction, I have considered the claim construction order dated December 18, 2013 of the United States District Court for the Central District of California in this case (hereinafter "Claim Construction Ruling"). I have reviewed the documents noted in Exhibit A. This study is ongoing, and I may supplement or amend these opinions based on the results of further analysis and in response to positions taken by Defendant and Counter-Claim Plaintiff Advanced Cleanup Technologies, Inc. and Advanced Enviornmental [sic] Group, LLC (collectively, "ACTI").

3. I am being compensated for my time spent in connection with this case at a rate of $200 per hour. Except for my consulting duties, I have no financial stake in this litigation, and my compensation is not contingent upon the outcome of this litigation.

II. SUMMARY OF OPINIONS

4. Based on my analysis of the '710 patent and Teboul and the materials identified above, as well as the legal principles explained to me, it is my opinion that claim 19 of the '710 patent is anticipated by clear and convincing evidence. My opinions are set forth in more detail below.

III. QUALIFICATIONS

5. I have studied and worked extensively in the fields of air pollution, environmental engineering, naval architecture, and mechanical engineering for the past seventeen years. I have extensive knowledge of diesel and internal combustion engines, their emissions, and control of those emissions, from cars, boats, and other sources.

6. The focus of my research has been in fundamental and applied fluid mechanics – in particular, the application of fundamental turbulence concepts to studies in environmental flows. In this area, I identify physical phenomena and build physical (laboratory) models that can successfully explain complex field observations or a part thereof. I also have experience developing idealized theoretical models to explain fluid dynamic processes. My approach has been to cross-fertilize field measurements with carefully designed laboratory experiments and simple theoretical analysis.

7. My early research focused on "engineering flows," specifically ships' propulsion and resistance. This research resulted in several polynomial models for the estimation of the power and resistance for the specific type of semi-displacement hull forms. In graduate school I focused my research on thermally driven environmental flows, motivated by tremendous air quality problems that are occurring in cities located in areas with complex terrain.

8. I currently focus on field experimental research on urban flows, specifically on urban dispersion (pollutants or toxic releases, industrial disasters or terrorist attacks) and parameterizations of turbulence within urban canyons.

9. I teach classes dealing with air pollution. The class Environmental Impacts of Energy Production & Conversion (ME136) is part of the Energy and Environment focus area within the Department of Mechanical Engineering. This class covers thermodynamics, heat transfer, and fluid mechanics as applied to the examination of the environmental impacts of energy production and conversion. Topics include pollution associated with fossil fuel combustion, environmental impacts of energy use, turbulent transport of pollutants, and principles used in the design of pollution control equipment. Many of my recent projects and field experiments involve air pollution and the study of emissions and how they travel and disperse in the atmosphere. I recently completed a project that modeled transportation emissions from cars, and I have worked on other projects involving distributed generation sources that involve the study of emissions from internal combustion engines and generators.

10. I am also involved in marine engineering. As an undergraduate, I majored in naval architecture, where I learned about boat building, including managing boat exhaust. I currently own a sailboat with a diesel engine, which I sail several times a month on average. I recently completed a project involving the impact of hydrogen injection in marine diesel engines for the California Air Resources Board (CARB). This project resulted in an article I submitted to the journal *Fuel* in 2011 entitled, “Effect of Hydrogen Injection on Emissions from a Two-Stroke Marine Diesel Engine.”

11. I have tested tugboat emissions in the Port of Los Angeles. This testing involved hybrid (diesel-electric) internal combustion engines for the

tugboats. I am on the doctoral qualifying committee for two doctoral candidates who are using this data for their Ph.D. work.

12. I am a member of The Society of Naval Architects and Marine Engineers (SNAME), The American Meteorological Society (AMS), and The American Society of Mechanical Engineers (ASME).

13. I received a B.Sc. degree in Mechanical Engineering and Naval Architecture from the University of Belgrade in Serbia in 1997 and a Ph.D. in Mechanical Engineering from Arizona State University in 2003.

14. After one year of postdoctoral research after receiving my Ph.D., I began teaching at UC Riverside in 2004 and have been teaching there for the last ten years, gaining tenure in 2010.

15. My *curriculum vitae* and publications list are attached as Exhibit B.

IV. LEGAL STANDARDS

A. Burden of Proof

16. Attorneys for CAEMI have informed me of a number of legal principles regarding patent validity that I have taken into account in forming my opinions. As an initial matter, it is my understanding that patent applications are reviewed and approved by examiners trained in the technical field of the invention. Because of this examination process, an issued patent is presumed to be valid over the prior art. Accordingly, there is a burden on a party challenging the validity of a patent – that party must prove that a patent is invalid by clear and convincing evidence. I further understand that this means that the party challenging the validity of a patent must demonstrate an abiding conviction that the truth of the factual contentions is highly probable.

17. Because of the presumption of validity of United States patents, I understand the burden of proving invalidity of the '710 patent is on CAEMI.

B. Anticipation

18. It has been explained to me that a claim may be invalidated by "anticipation."

19. It has been explained to me that under the doctrine of anticipation in effect when the '710 patent issued (under 35 U.S.C. § 102), a claim may be anticipated if it is not new – that is, if there is a single prior art reference that discloses, explicitly or inherently, all of the limitations of the patent claim.

V. CLAIM 19 OF U.S. PATENT NO. 7,258,710 IS ANTICIPATED

A. Level of Ordinary Skill in the Art

20. Based on my years as a professor of graduate and undergraduate students, and as an advisor to Master's and Ph.D. candidates in Mechanical Engineering, I believe that the definition of a person of ordinary skill in the art relating to the '710 patent is one who would have at least a B.S. degree in mechanical or environmental engineering, or an equivalent formal education, and would have at least two years of work or research experience involving diesel emissions or related areas. One of ordinary skill in the art could also have a Master's degree in one of these same fields and at least one year of relevant work or research experience.

B. Summary of the '710 Patent

21. The '710 patent (attached as Exhibit C) is directed to a maritime emissions control system. The emissions comprise pollutants in exhaust produced when an engine burns diesel fuel.

22. The '710 patent was filed April 29, 2004 and does not claim priority from any other application or publication.

23. As shown in '710 patent Fig. 2A (right), two ships (12, 24) are positioned next to one another in the sea water. One ship (12 – the "Unpowered Seagoing Barge" or "USB") carries an "emissions control unit" (not shown) to process exhaust received from the second ship (24 – the "Ocean Going Vessel" or "OGV"), coming into port.

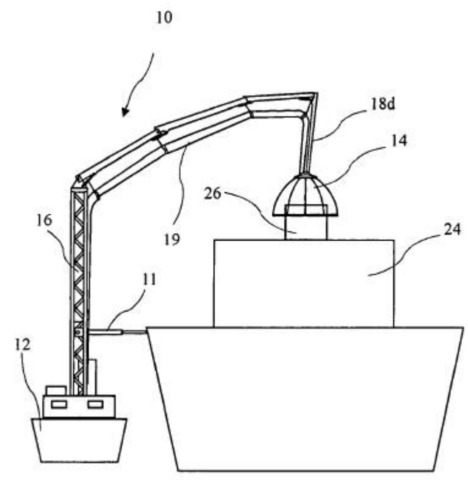


FIG. 2A

'710 Patent Fig. 2A

24. The OGV emits the exhaust through a stack (26), and a bonnet (14) captures the exhaust which is drawn to the emissions control unit on the USB through the duct (19).

C. Claim 19 of the '710 Patent

25. This declaration is directed to claim 19 of the '710 patent. Claim 19 provides:

> 19. A method for emissions control, the method comprising:
>
> securing a bonnet over a stack of an Ocean Going Vessel (OGV) to capture exhaust;
>
> drawing the exhaust captured by the bonnet through a duct to an emissions control unit; and
>
> processing the exhaust by the emissions control unit.

D. Claim Construction

26. I understand the following claim construction, which is compiled from the Court's Claim Construction Ruling, dated December 18, 2013, applies to claim 19 as follows:

U.S. Patent No. 7,258,710	
Disputed Claim Term	**Construction**
bonnet	[the term does not require construction]
stack	a structure extending from the ship that emits exhaust
securing a bonnet over a stack	[the term does not require construction]

E. Summary of the Bases of Opinions

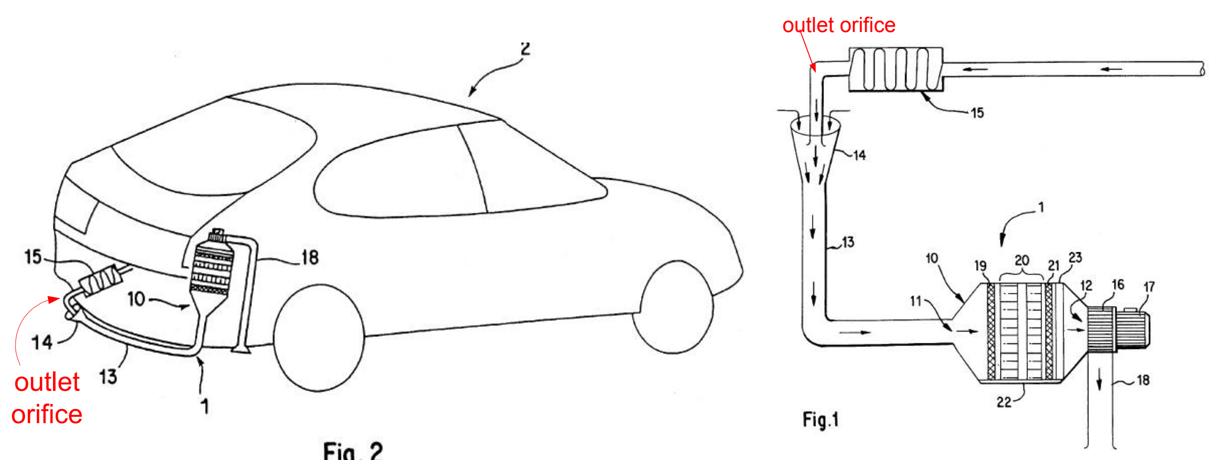
27. I have reviewed the '710 patent and U.S. Patent No. 6,185,934. I find that U.S. Patent No. 6,185,934 anticipates claim 19 of the '710 patent.

F. Summary of Teboul

28. Teboul (attached as Exhibit D) is directed to an emissions control system that can be used to process exhaust produced when a car's, boat's, or other motor vehicle's engine burns diesel fuel.

29. Teboul issued on February 13, 2001.

30. As shown in Teboul Figs. 1 and 2 (below, annotated in red), a motor vehicle 2 is connected to an "exhaust silencer box" (*e.g.*, a muffler) 15 that has an



Teboul Figs. 2 and 1 (annotated)

outlet orifice (*e.g.*, a tailpipe) that penetrates a conical nozzle 14. Conical nozzle 14 is connected to an emissions filtering device 1, which is used to filter internal combustion engine exhaust gases that come out of the outlet orifice, via supply line 13. Emissions filtering device 1 includes filtering chamber 10 having an inlet 11

and an outlet 12. Filtering chamber 10 further includes filters 19 and 21, electrostatic filtering means 20, active carbon filter 23, and residues container 22. Filtering chamber 10 is in fluid connection with intake means 16, which may be a motor turbine and which is driven by electric motor 17.

G. Anticipation of Claim 19 of the '710 Patent by Teboul

31. Claim 19 of the '710 patent includes a preamble plus three limitations. Each of them is found in Teboul.

32. Like the '710 patent, Teboul discloses a method for controlling exhaust emissions by using a conical nozzle which is secured as a bonnet over an exhaust emission structure. Like the '710 patent, Teboul discloses that the exhaust is captured by the conical nozzle and drawn through a supply line, which is a duct, to a filtering device, which is an emissions control unit. The filtering device then processes the exhaust.

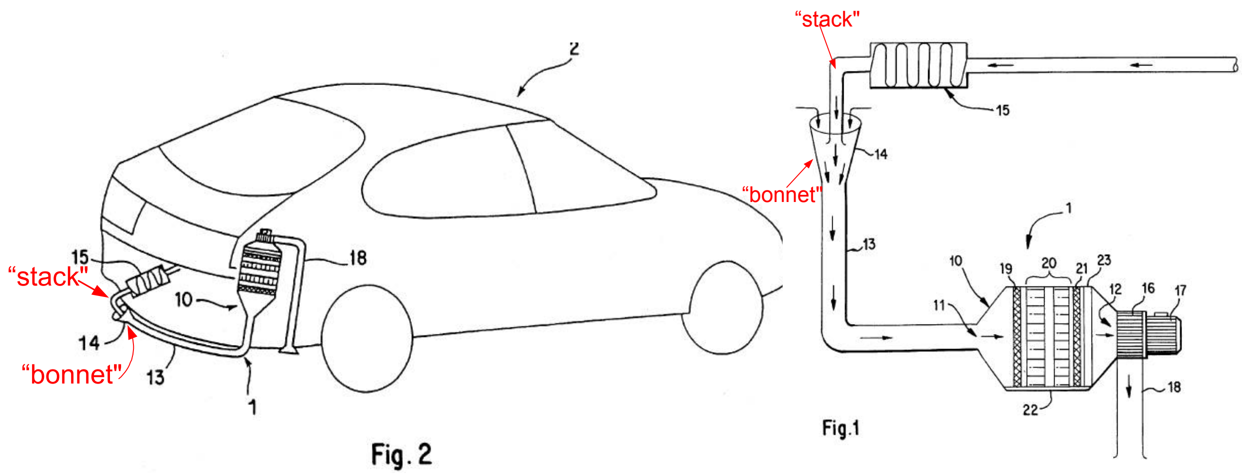
1. Preamble: "A method for emissions control, the method comprising"

33. Teboul discloses the subject matter of Claim 19's preamble, which recites "[a] method for emissions control." Teboul discloses methods of emissions control. Teboul is directed to "the elimination of polluting components, or of solid, liquid or gaseous impurities, from the exhaust gasses of an internal combustion engine," including a diesel engine. Teboul*,* 1:8-11. Removing impurities from exhaust gases is emissions control.

2. "securing a bonnet over a stack of an Ocean Going Vessel (OGV) to capture exhaust"

34. The Court did not construe "bonnet" other than to say that a bonnet does not require a "cage and shroud." Claim Construction Ruling at 8. Teboul discloses a bonnet, which it describes as a "conical nozzle 14," which is attached to

the "supply line" and captures exhaust gases. Teboul, 3:18-30. Teboul Figs. 1 and 2 are annotated below in red to indicate the "conical nozzle 14," which is a bonnet.



Teboul Figs. 2 and 1 (annotated)

35. The Court construed "stack" to mean "a structure extending from the ship that emits exhaust." Claim Construction Ruling at 8. Teboul discloses an "outlet orifice of an exhaust silencer box 15 of a motor vehicle 2," which is a stack. Teboul, 3:28-31. Alternatively, the "exhaust manifold of the internal combustion engine" is a stack. Teboul, 2:66-3:2. Teboul discloses that conical nozzle 14 (*i.e.*, the "bonnet") may be connected either to the outlet of exhaust silencer box 15 (*i.e.*, the tailpipe on a muffler) or directly to the engine exhaust manifold. *Id.*; *see also* Teboul, 3:37-40. Either the exhaust manifold or the "outlet orifice" are "stacks," because each is a "structure extending from the [vehicle and] that emits exhaust." The outlet orifice (*i.e.,* tailpipe), in particular, extends from the vehicle, as illustrated in the above annotated version of Figs. 1 and 2.

36. The Court did not construe "securing a bonnet over a stack." Claim Construction Ruling at 12. In Teboul, the bonnet is "connected" to the stack. For example:

> The supply line can be connected to the outlet of the exhaust silencer box or directly to the outlet of the exhaust manifold of the internal combustion engine and comprises means adapted to receive the corresponding outlet.

Teboul, 2:66-3:2.

37. Teboul Fig. 1 is shown on the previous page, annotated to depict the locations of the “stack” and “bonnet” and showing how they are connected such that the bonnet is secured over the stack.

38. Below, Teboul Fig. 1 is inverted to show the correspondence with Fig. 3B of the ’710 patent. The bonnet (conical nozzle 14) and stack (outlet orifice) are arranged coaxially such that the bonnet is wider than and surrounds or fits over a portion of the stack. The stack extends inside a portion of the bonnet. Since conical nozzle 14 and supply line 13 are connected to the outlet orifice, and conical nozzle 14 is wider than and fits over the outlet orifice, the conical nozzle (“bonnet”) is secured over the outlet orifice (“stack”).

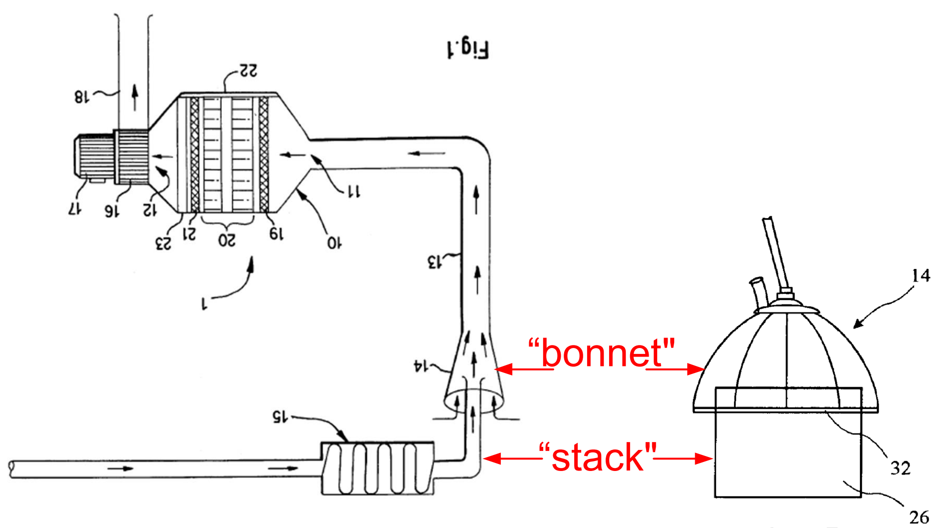


FIG. 3B

Teboul Fig. 1	‘710 patent, Fig. 3B

39. Fig. 3B of the ‘710 patent illustrates stack 26 extending inside a portion of bonnet 14, in the same way that Teboul depicts the tailpipe extending into the conical nozzle. In both cases the “bonnet” is secured over the stack.

40. Although the figures in Teboul are directed to a car, Teboul explicitly recites that its apparatus is applicable to other types of vehicles, including marine vessels. For example, Teboul states that its apparatus “proposes a filtering device

which is compact and adaptable to ***any motor vehicle***." Teboul, 1:62-63 (emphasis added). And "[i]n particular, thanks to its structure, this device is efficient, at low speeds and at high speeds, from the time of starting to the time of stopping the internal combustion engine of ***any motor vehicle whatsoever*** (car, ***boat***, . . .), without choking the engine." *Id.*, 5:15-19 (emphasis added). Moreover, Teboul discloses that its apparatus can be used with "exhaust gasses of a diesel engine," *id.*, 1:13, and most marine engines are diesel engines. Thus Teboul discloses that its apparatus may be used with a boat, a ship, or other ocean going vessel.

41. Finally, the purpose of Teboul's conical nozzle 14 (*i.e.*, the bonnet) is to "capture exhaust." Teboul's apparatus "receive[s] the exhaust gasses from the outlet" orifice. Teboul, 6:59-60. Teboul discloses ways to optimize the capture of exhaust so that it can penetrate into supply line 13 via conical nozzle 14 and be carried to filtering device 1. For example:

> A line 13 for supplying exhaust gasses and ambient cool or cooling air is connected, by one of its ends, to the inlet 11. The other end of the supply line 13 is provided with an opening whose inlet orifice allows the penetration into the supply line of exhaust gasses coming from an internal combustion engine as well as the flow of ambient cooling air.
>
> In this case, this opening consists of a conical nozzle 14 receiving the outlet orifice of an exhaust silencer box 15 of a motor vehicle 2, as illustrated in FIG. 2.

Teboul, 3:21-31.

42. In other words, the inlet orifice of supply line 13 *is* conical nozzle 14 (*i.e.*, the bonnet). The bonnet thus "allows the penetration into the supply line of exhaust gasses." This means that the conical nozzle captures exhaust.

3. "drawing the exhaust captured by the bonnet through a duct to an emissions control unit"

43. Teboul's conical nozzle 14 (the bonnet) is an inlet orifice for supply line 13. Supply line 13 is a "duct to an emissions control unit."

44. The exhaust that is captured by the bonnet is drawn through supply line 13 (the duct):

> A line 13 for supplying exhaust gasses and ambient cool or cooling air is connected, by one of its ends, to the inlet 11. The other end of the supply line 13 is provided with an opening whose inlet orifice ***allows the penetration into the supply line of exhaust gasses*** coming from an internal combustion engine as well as the flow of ambient cooling air.

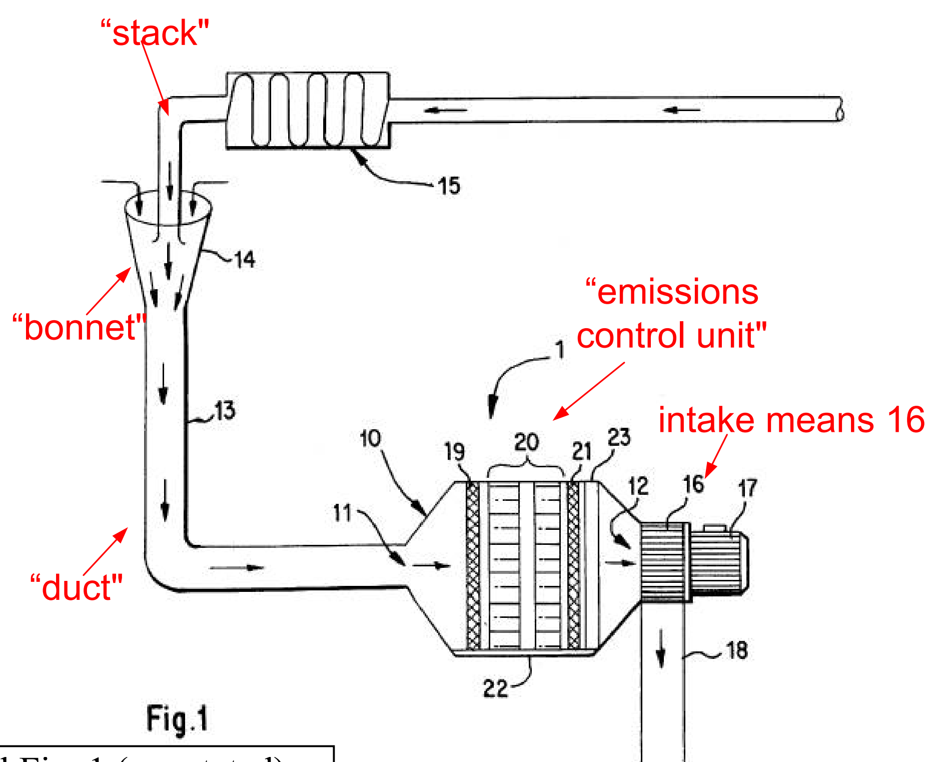
Teboul, 3:21-27 (emphasis added).

45. Teboul describes the flow of exhaust gases through the filtering means (*i.e.*, the "emissions control unit") as "drawing" the exhaust:

> The combination of a mechanical filter, electrostatic filtering means and the ***drawing*** through these things of ***a mixture of hot exhaust gasses and ambient cooling air*** makes it possible to filter these exhaust gasses in a particularly efficient and simple manner.

Teboul, 2:17-21 (emphasis added).

46. Supply line 13 (the duct) is connected to filtering device 1 (the "emissions control unit") which receives the exhaust gases. Intake means 16, a motor turbine, draws the exhaust from the engine. These features are indicated in the following annotated version of Fig. 1:



Teboul Fig. 1 (annotated)

47. Filtering device 1 is an emissions control unit because it controls the emissions of the vehicle by filtering pollutants from the exhaust. For example, filtering device 1 is described as comprising a filtering chamber 10, a "filter for coarse solid particles" and "droplets, as well as a filter comprising a metal casing and several layers of very fine meshes, or an impingement-type filter." Teboul, 4:13-17. It also comprises "electrostatic filtering means 20." Teboul, 4:17-18. The result is described as being particularly useful for "the filtering out of lead particles contained in their exhaust gasses." Teboul, 5:20-23.

48. Thus, Teboul discloses allowing the penetration into supply line 13 of exhaust gases captured by conical nozzle 14, the exhaust being drawn to emissions filtering device 1, which is "drawing the exhaust captured by the bonnet [14] through a duct [13] to an emissions control unit [1]."

4. "processing the exhaust by the emissions control unit"

49. Teboul's filtering device 1 (the "emissions control unit") performs numerous steps on the exhaust gases, each step of which processes the exhaust. Teboul refers to this as "the processing of the exhaust":

> Preferably, another filter for solid particles and droplets is mounted downstream of the electrostatic filtering means, in the filtering chamber. Thus, the ***processing of the exhaust*** gasses in the electrostatic filtering means takes place in the whole of useful volume of these means, with no dead volume which could result in load loss phenomena.

Teboul, 2:33-38 (emphasis added). Filtering device 1 includes "electrostatic filtering means 20," *id*, 4:17-18, which performs this processing of the exhaust.

50. Filtering device 1 (the "emissions control unit") includes filtering chamber 10, which includes a "filter [19] for coarse solid particles . . . and droplets, as well as a filter comprising a metal casing and several layers of very fine meshes, or an impingement-type filter." Teboul, 4:14-17. Filtering particles and droplets is "processing the exhaust." Filter 19 may be used with a diesel engine. *Id.*, 5:5-10.

A "second filter 21," the same type as filter 19, also processes the exhaust. *Id.*, 4:34-35. An "active carbon filter 23" further processes the exhaust using gas adsorption, *id.*, 4:56-61, which is also processing the exhaust. The result of the filtering in filtering device 1 is described as being particularly useful for "the filtering out of lead particles contained in their exhaust gasses." *Id.*, 5:20-23. Again, this is a form of processing the exhaust.

51. Thus, Teboul includes the limitation "processing the exhaust by the emissions control unit."

H. Conclusion

52. Based on the foregoing, Teboul discloses the preamble plus the three limitations of claim 19 of the '710 patent, thus rendering the claim anticipated.

I declare under penalty of perjury that the foregoing is true and correct.

Executed this 20TH day of May, 2014, at Riverside, California.

Marko Princevac

Marko Princevac, Ph.D.

Exhibit 6

United States Patent [19]
Liu et al.

[11] 4,338,784
[45] Jul. 13, 1982

[54] METHOD OF RECYCLING COLLECTED EXHAUST PARTICLES

[75] Inventors: **Benjamin Y. H. Liu**, North Oaks; **David B. Kittelson**, Minneapolis; **Daniel F. Dolan**, St. Anthony; **David Y. H. Pui**, Minneapolis, all of Minn.

[73] Assignee: **The Regents of the University of Minn.**, Minneapolis, Minn.

[21] Appl. No.: **215,457**

[22] Filed: **Dec. 11, 1980**

Related U.S. Application Data

[60] Division of Ser. No. 68,703, Aug. 22, 1979, Pat. No. 4,316,360, which is a continuation-in-part of Ser. No. 38,077, May 11, 1979, Pat. No. 4,304,096.

[51] **Int. Cl.**[3] **F01N 3/00**
[52] **U.S. Cl.** **60/274**; 60/275; 60/279
[58] **Field of Search** .... 60/273, 274, 275, 278, 60/279; 55/103, DIG. 30

[56] **References Cited**

U.S. PATENT DOCUMENTS

1,756,897	4/1930	Bilsky .	
1,884,086	10/1932	Miller .	
2,100,155	11/1937	Beran	183/71
2,708,486	5/1955	Hedberg	183/7
2,771,736	11/1956	McKinley	60/275
2,862,354	12/1958	Barnhart	60/30
2,924,293	2/1960	Sprague	183/7
2,989,144	6/1961	Styrie	60/275
3,034,290	5/1962	Gary	60/30
3,074,390	1/1963	O'Laughlin	123/119
3,083,084	3/1963	Raymond	23/288
3,100,376	8/1963	Potter	60/279
3,157,479	11/1964	Boles	55/146
3,180,083	4/1965	Heller	60/29
3,184,400	5/1965	Magnus	204/193
3,184,901	5/1965	Main	55/102
3,440,800	4/1969	Messen-Jaschin	55/122
3,526,081	9/1970	Kusters	55/127
3,531,931	10/1970	Caruso	60/30
3,558,286	1/1971	Gourdine	23/288
3,618,314	11/1971	Krebs	60/30
3,620,008	11/1971	Newbold	60/30
3,755,120	8/1973	Kinser	204/164
3,936,280	2/1976	Briggs	55/3
3,976,448	8/1976	Eng et al.	60/275
3,979,193	9/1976	Sikich	55/3
3,999,967	5/1955	Aoi	55/124

FOREIGN PATENT DOCUMENTS

411807	9/1932	United Kingdom	60/275
1022714	3/1966	United Kingdom	60/275

OTHER PUBLICATIONS

Bertodo, R., T. W. E. Downes, and J. D. Middlemiss, "Evolution of a New Combustion System for Diesel Emission Control", SAE Paper #741131 (1974).
Wilson, R. P., Jr., E. B. Muir, and F. A. Pellicciotti, "Emissions Study of a Single Cylinder Diesel Engine", SAE Paper #740123 (1974).
Patterson, D. J., and N. A. Henein, *Emissions from Combustion Engines and Their Control*, Ann Arbor (1972).
Pochernegg, S. J., "Efficient and Clean Diesel Combustion", SAE Paper #75087 (1975).
Walden, C. J., "Reduction of Emissions from Diesel Engines", SAE Paper #730214 (1973).
Kittelson, D. B., D. F. Dolan, R. B. Diver, and E. Aufderheide, "Diesel Exhaust Particle Size Distributions—Fuel and Additive Effects", SAE Paper #780787 (1978).
Schmidt, H. H., "Axycatalytic Scrubbers", *Canadian Mining Journal*, vol. 2, No. 10, p. 68 (Oct. 1971).
Springer, K. J., and R. C. Stahmas, "Removal of Exhaust Particulate from a Mercedes 300 Diesel Car", SAE Paper #770716 (1977).

Primary Examiner—L. J. Casaregola
Attorney, Agent, or Firm—Burd, Bartz & Gutenkauf

[57] **ABSTRACT**

The method and apparatus for controlling particulate emissions from a combustion apparatus, as a diesel engine. Diesel engine exhaust particles are electrically charged during the formation of the particles in the engine combustion chamber. A particle collector is used to collect the electrically charged particles on collecting structures connected to a high voltage power supply and ground. The collecting structures of the particle collector can be a plurality of parallel metal plates,

spaced cylindrical rods, or concentrically located cylindrical members. A fibrous matrix can be located adjacent the particle collecting structure to collect the charged particles as they move through the matrix. In one embodiment, the collected particles separate from the collecting structures and return to the engine intake. In another embodiment, a removable collecting cartridge has electrically conductive plates for collecting the charged particles. The entire cartridge is removed for cleaning or replacement. The hot exhaust gas from the engine can be used to oxidize the collected particles. The collected particles that are not oxidized can be separated from the collecting structures and re-entrained into the gas. The re-entrained particles are larger than the particles formed in the combustion apparatus. The large particles can be removed by a downstream particle collection device or mixed with fuel for the engine.

10 Claims, 30 Drawing Figures

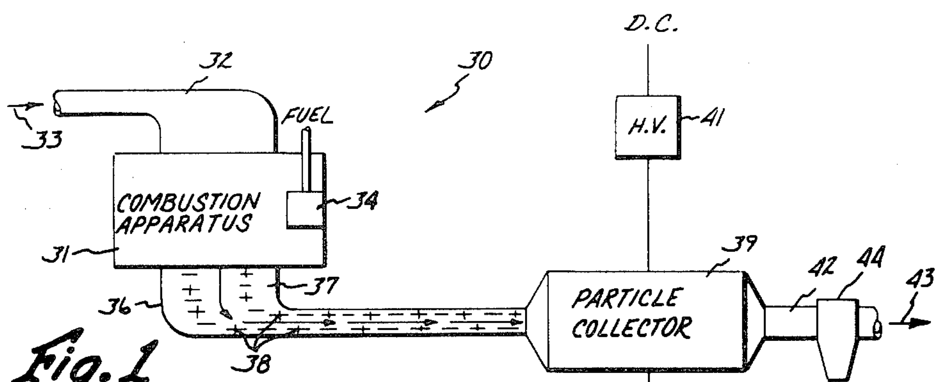


Fig. 1

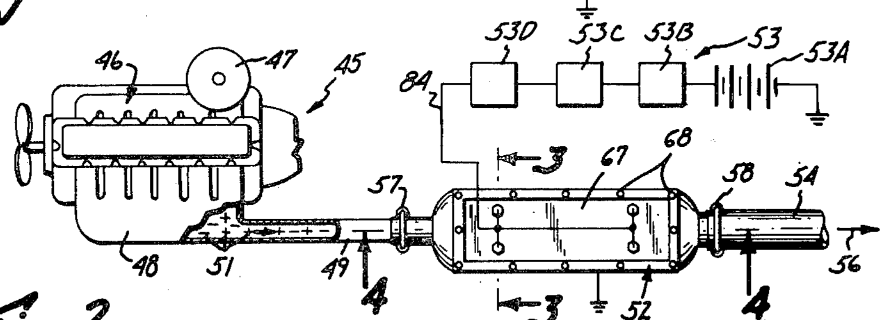


Fig. 2

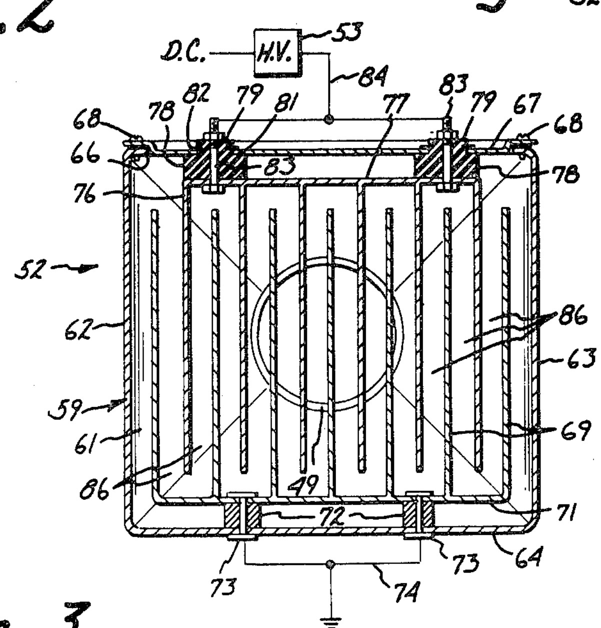
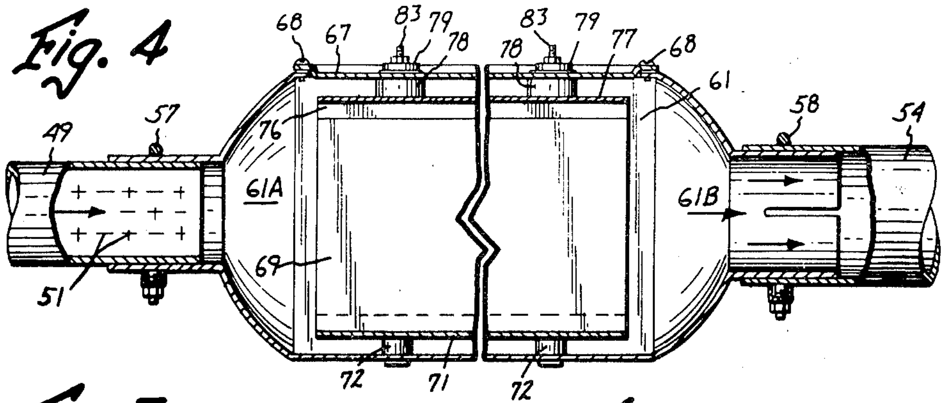


Fig. 3

Fig. 4



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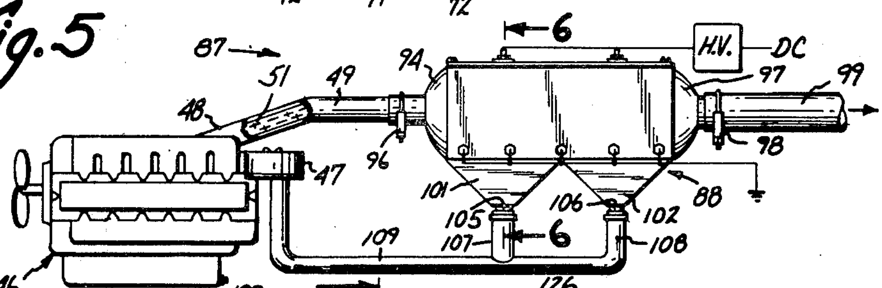

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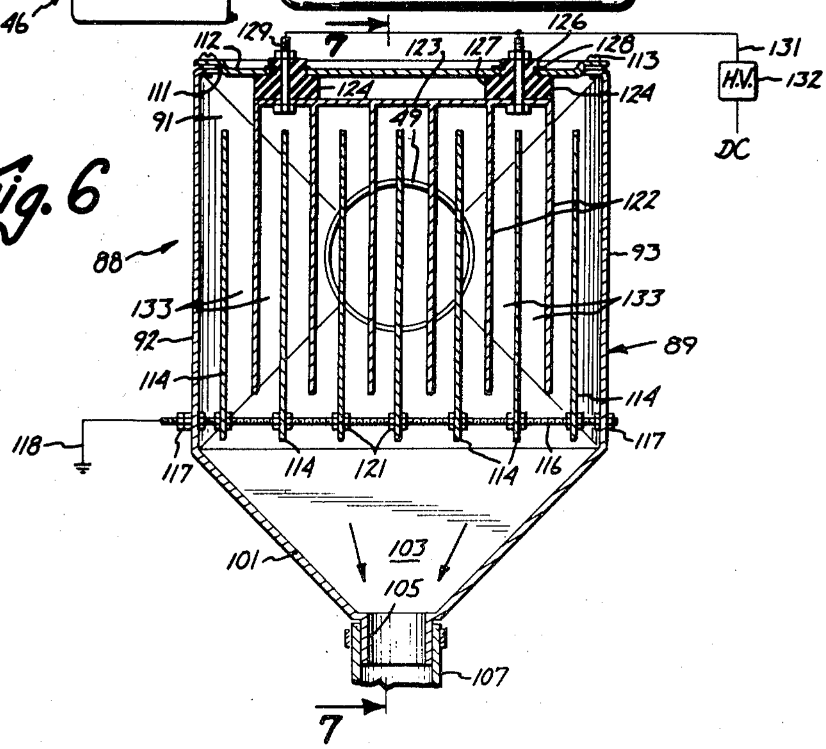

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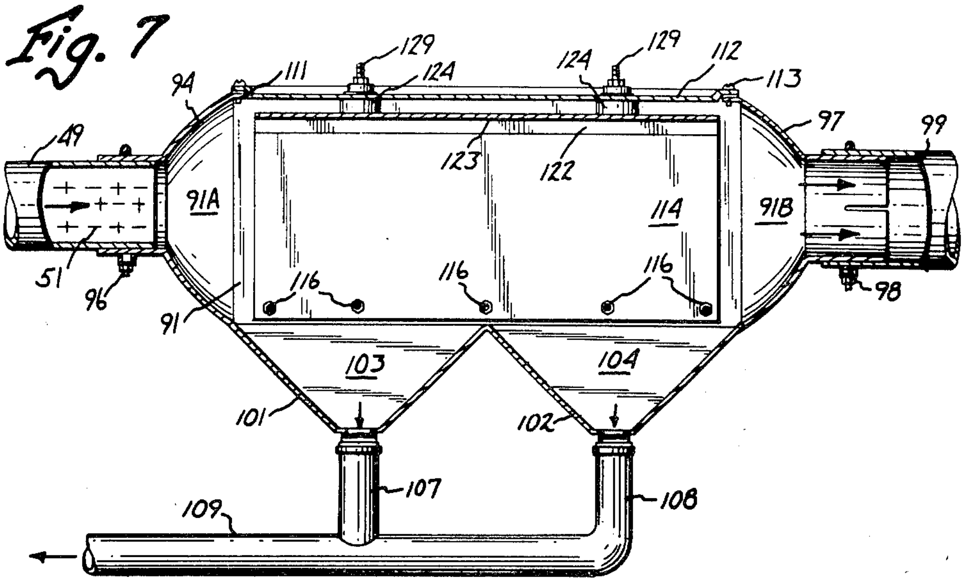
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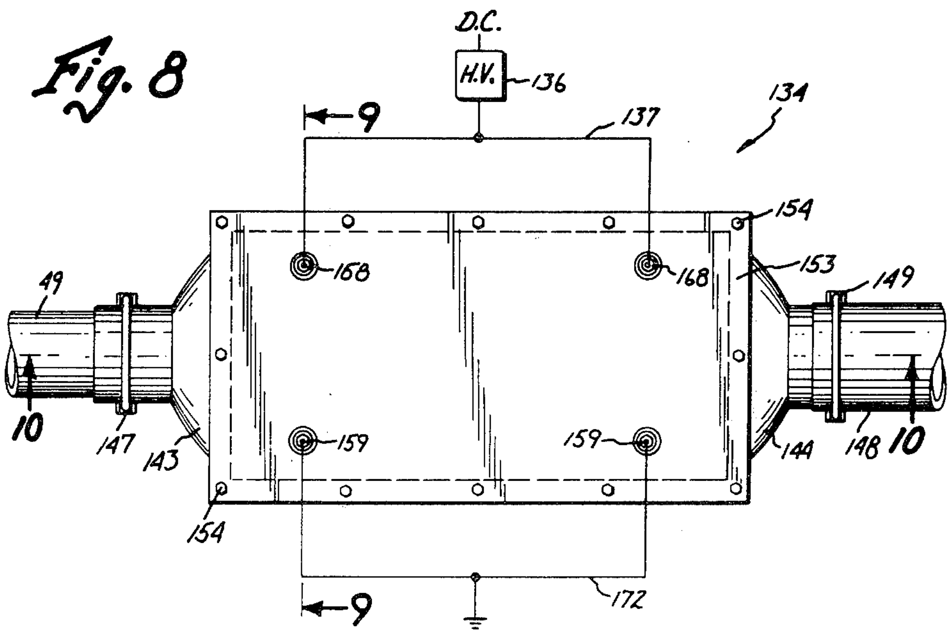
Fig. 8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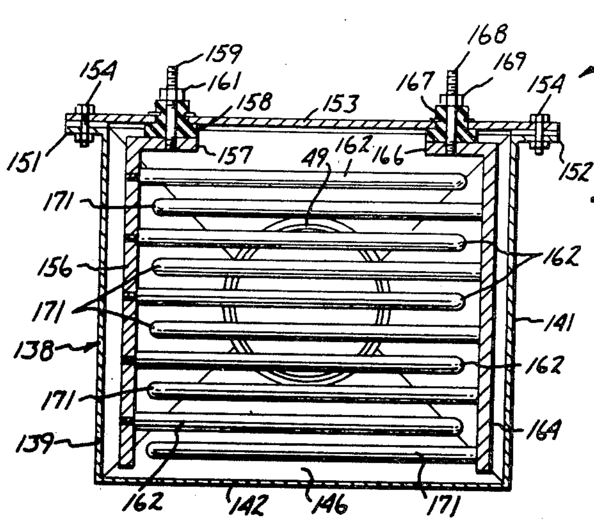

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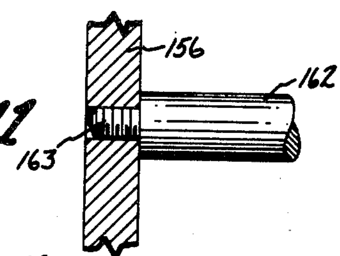
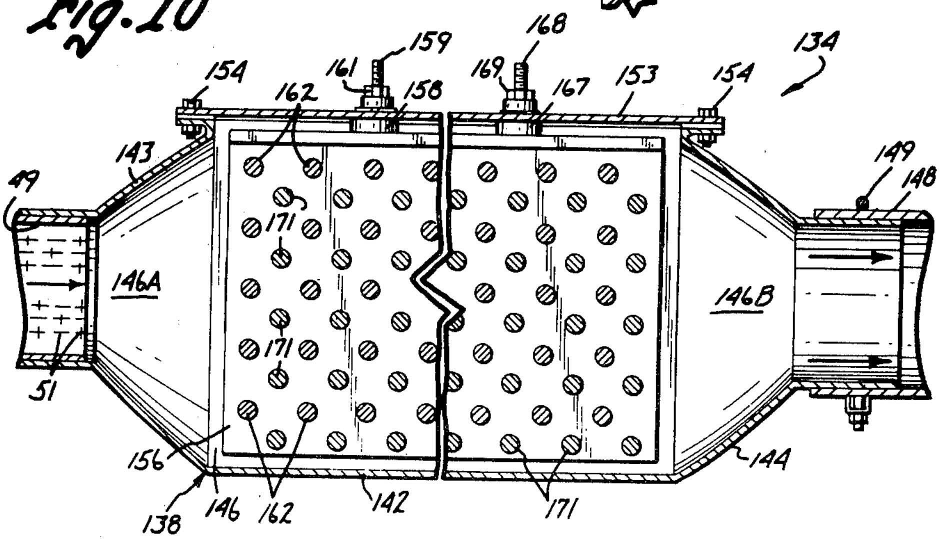


Fig. 11

Fig. 10



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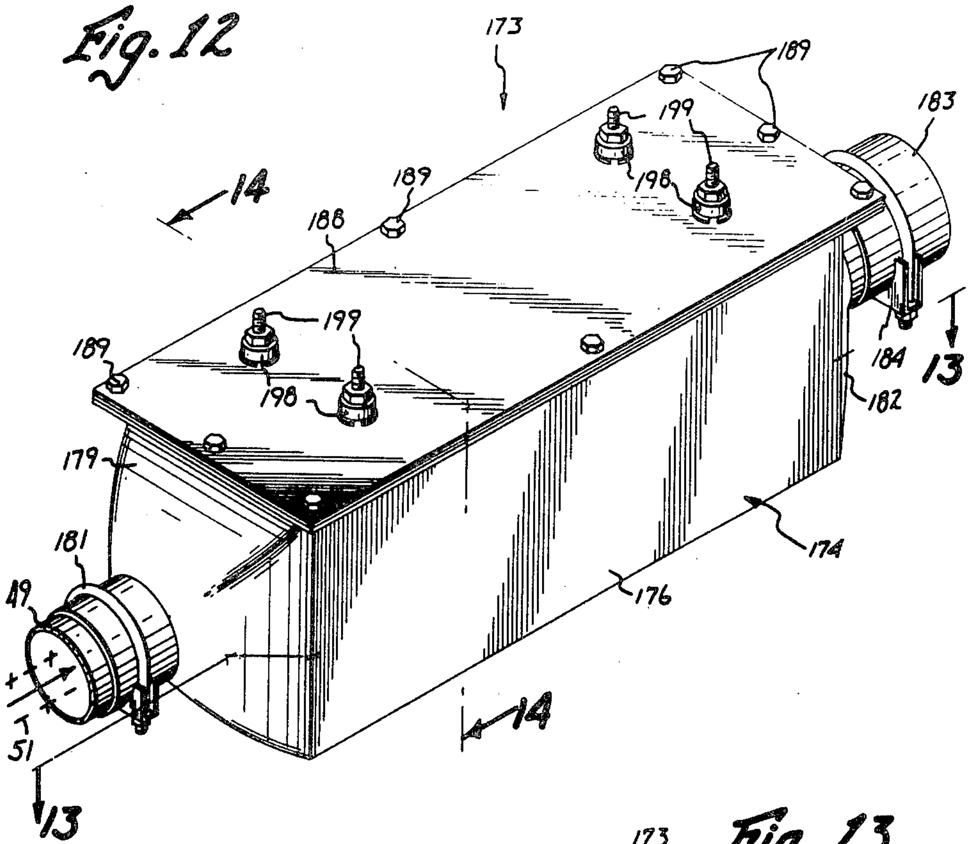
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Fig. 13

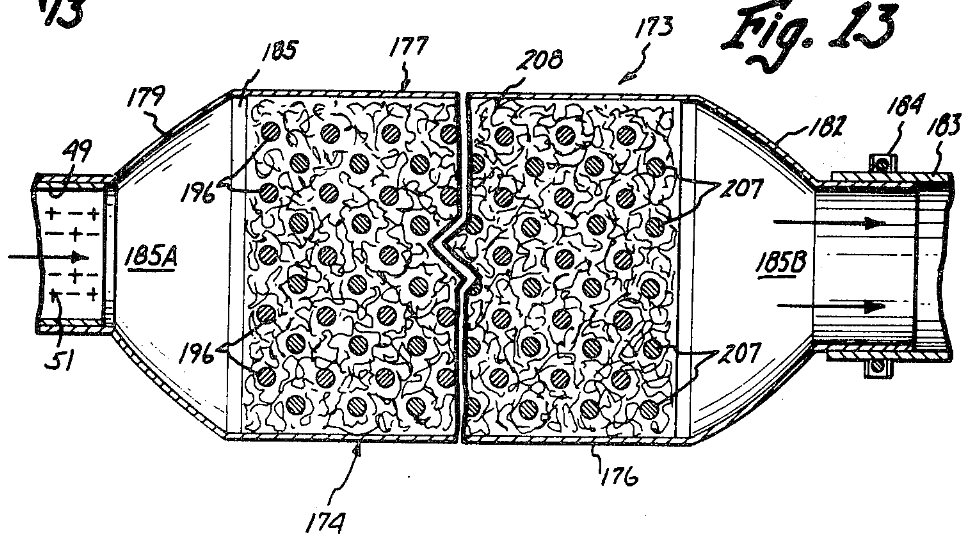
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Fig. 14

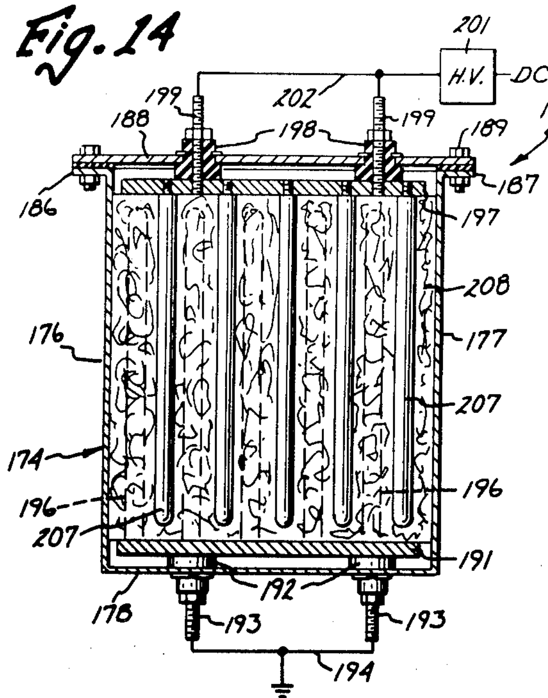


Fig. 16

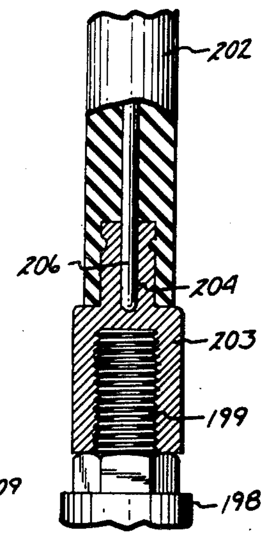
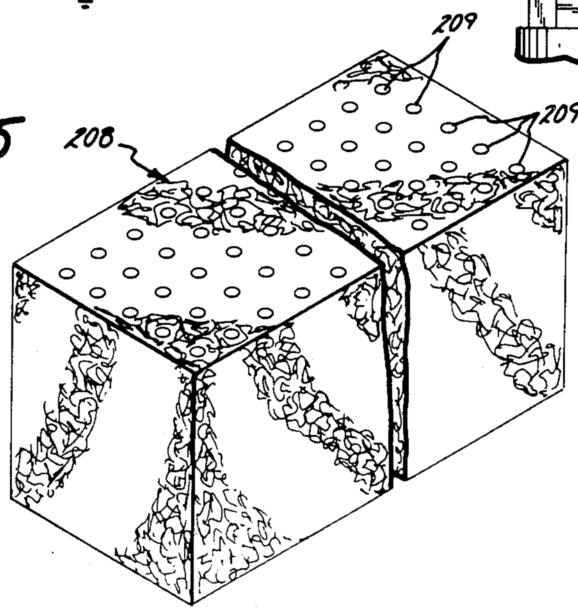


Fig. 15



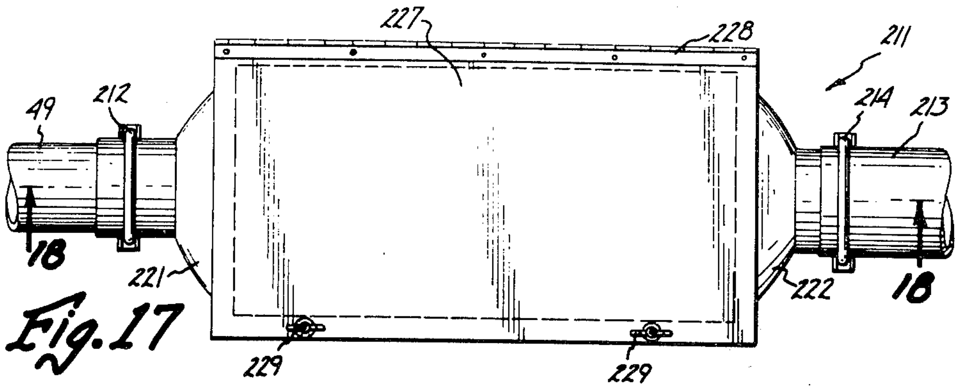


Fig. 17

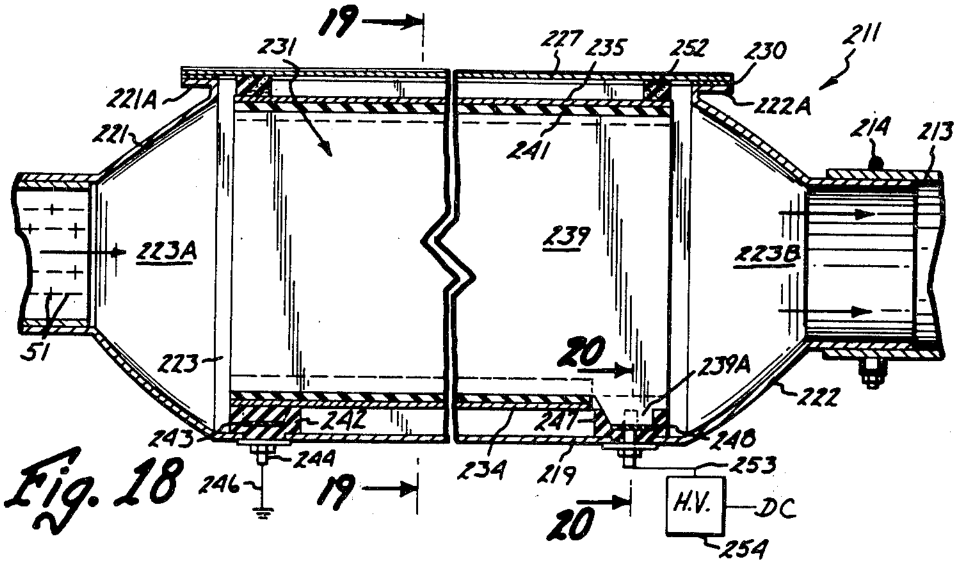
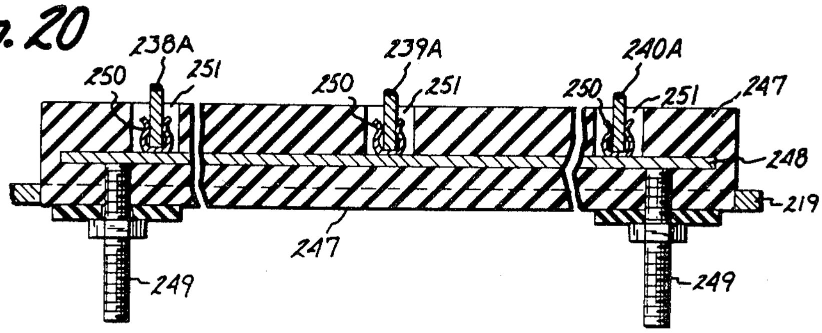


Fig. 18

Fig. 20



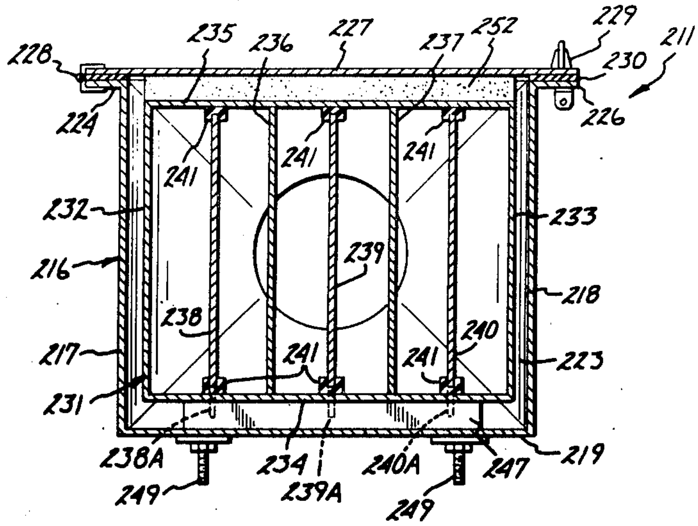

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Fig. 19

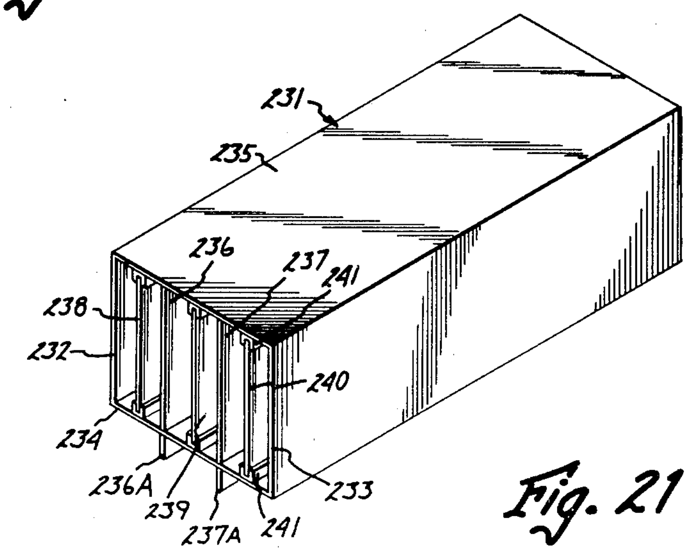
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Fig. 21

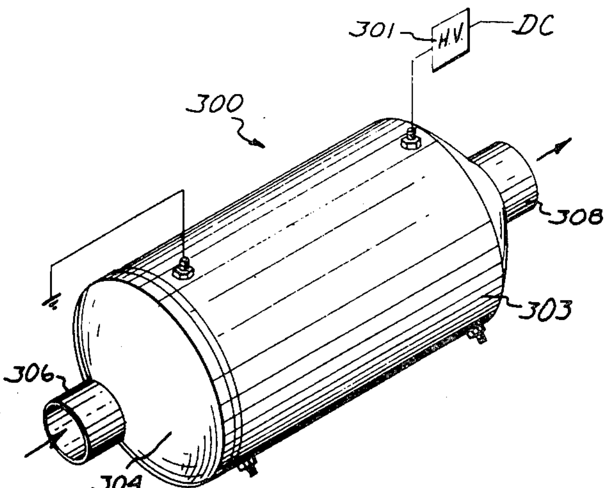


Fig. 22

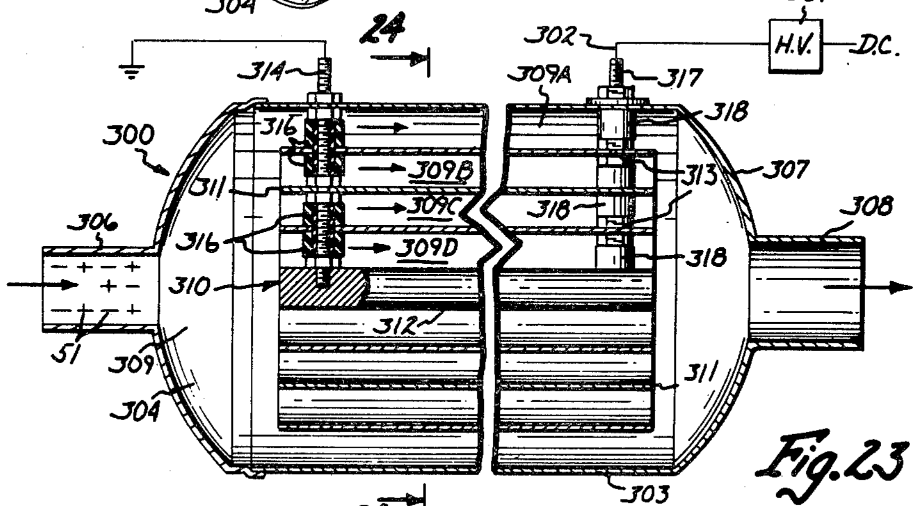


Fig. 23

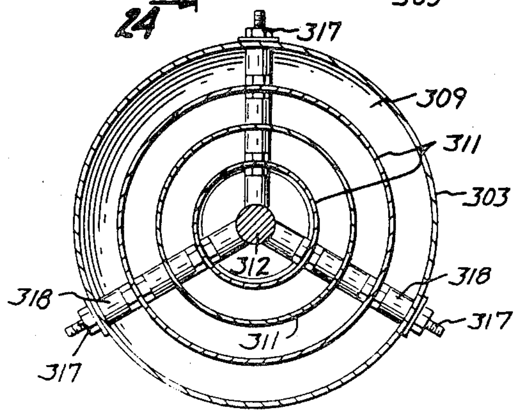


Fig. 24

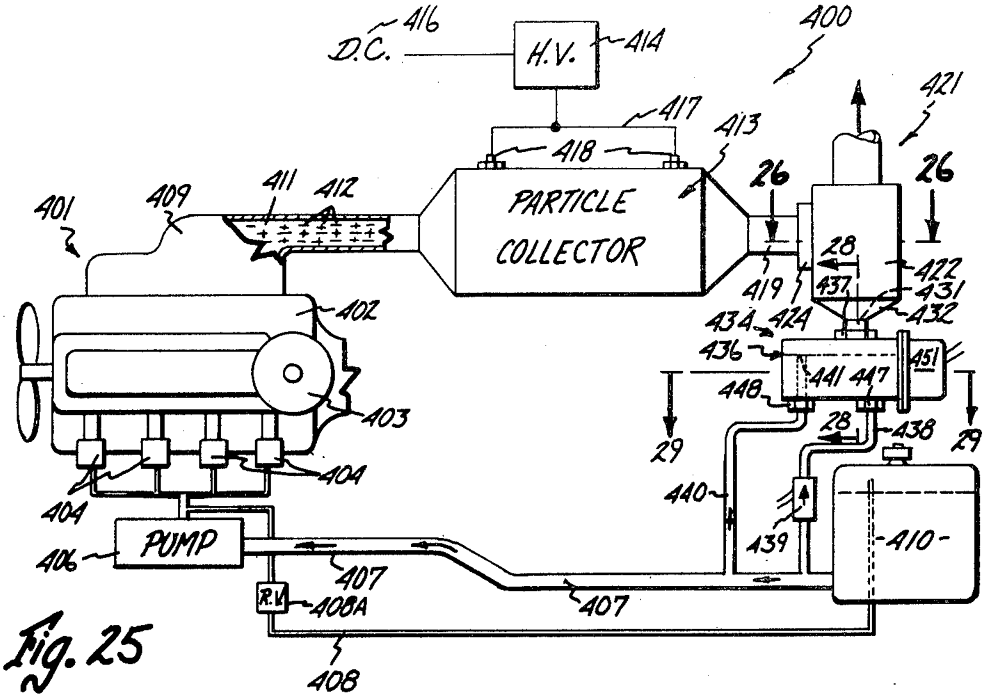
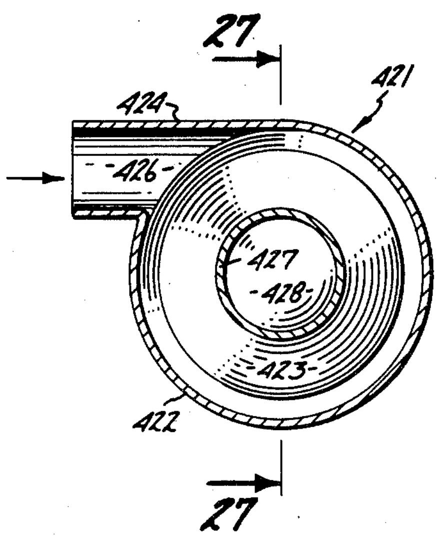


Fig. 25



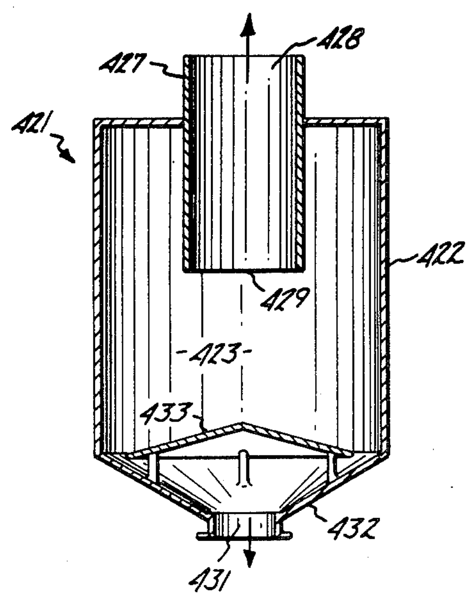


Fig. 26

Fig. 27

Fig. 29

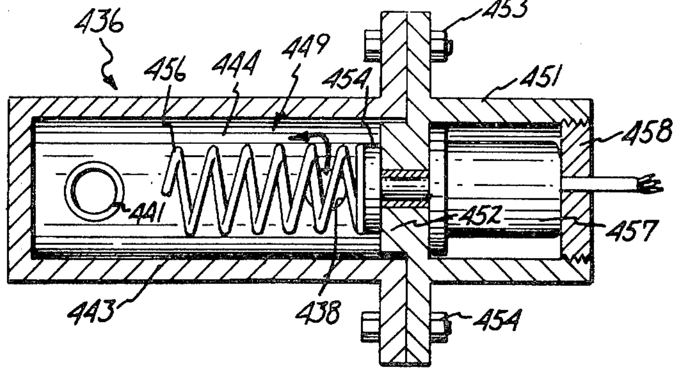
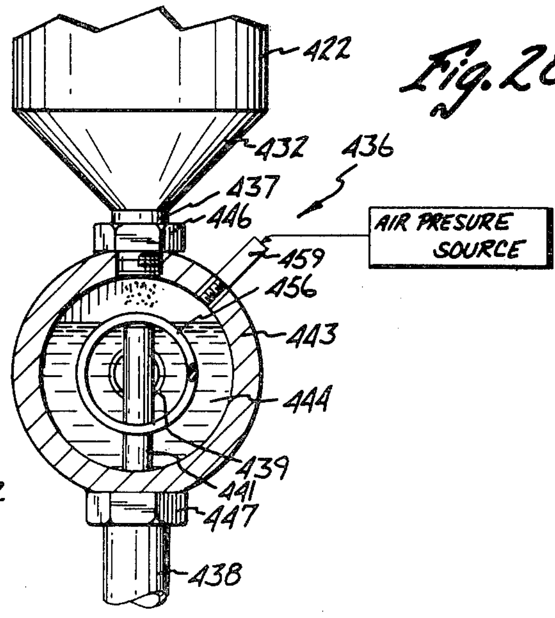


Fig. 28



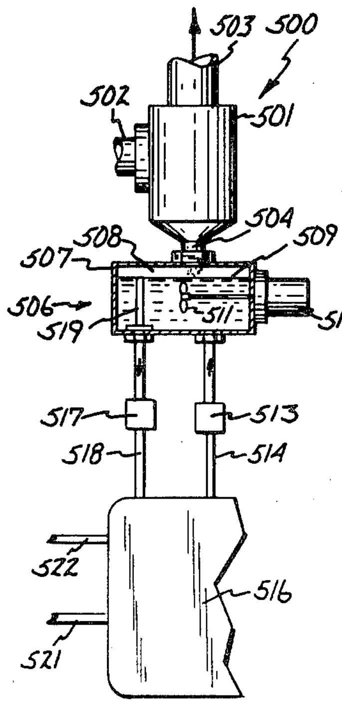


Fig. 30

METHOD OF RECYCLING COLLECTED EXHAUST PARTICLES

This is a division, of application Ser. No. 068,703 filed Aug. 22, 1979 (U.S. Pat. No. 4,316,360), which is a C.I.P. of application Ser. No. 038,077 filed May 11, 1979 (U.S. Pat. No. 4,304,096).

SUMMARY OF INVENTION

The invention relates to a method and means for controlling particulate emissions from a combustion system having combustion means, as a diesel engine. Diesel engine exhaust particles consist mainly of roughly spherical carbonaceous nuclei which have grown by coagulation into chain aggregates. These particles are primarily elemental carbon, but may also contain significant quantities of absorbed or condensed hydrocarbons, hydrocarbon derivatives, sulfur compounds and other materials. Similar particles are formed by other hydrocarbon combustion systems such as oil-fired furnaces and gas turbine engines.

A property of the diesel engine exhaust particulates or particles is that a significant fraction of the particles are electrically charged during the formation of the particles in the engine combustion chambers. We have discovered that the charged particles are a high percentage of all of the exhaust particles. These particles include carbon, absorbed or condensed hydrocarbon, hydrocarbon derivatives, and sulfur compounds. Some of these particles do not carry an electrical charge. This electrical property of the diesel engine exhaust is utilized to effect particle removal by a particle collector having an electric field. Tests have shown that from 72% to 88% of the particles by mass in the diesel exhaust are electrically charged. The charge distribution on the particles is nearly symmetrical. There are nearly as many positively charged particles as there are negatively charged particles, i.e., the particle charge is bi-polar. The overall charge on the particles is nearly zero and the particles as a whole are essentially an electrical neutral mass of particles.

The particle collector removes both the positive and negative charged particles. The particle collector utilizes a static electric field without a corona charging device. In the present invention, the charged particles move directly from the diesel engine to the particle collector where they are collected by the static electric field. Heat from the engine exhaust gases may be used to oxidize the collected particles. The particles that do not oxidize or are not subjected to sufficient heat to oxidize build up as particle deposits on the first and second particle collecting surface means of the collector. These deposits fracture and break off the collecting surfaces and re-entrain in the gas flowing through the collector. The re-entrained particles are larger than the sub-micron particles formed in the diesel engine. A collection device, as an inertial separator or scrubber, downstream of the separator is useable to remove the larger particles from the gas.

The first embodiment of the particle collector has a number of parallel metal plates. Alternate plates are connected to ground and to a source of high voltage. The exhaust gas, including the charged particles from the diesel engine, flows between the spaces between the plates. The electric field existing between the plates causes the particles to be attracted to the plate with the

opposite polarity whereby the particles are collected on the plate.

In a second embodiment of the particle collector, a collecting passage for particles is located below the plates. The deposited particles fall into the collecting passage and are fed back into the intake of the engine. The advantage of this arrangement is that accumulated particles are returned to the engine thereby reducing the need to service and clean the collection plates. Part of the exhaust gases are also returned to the engine intake. The recirculation of exhaust gases controls NO_x emissions.

In the third embodiment of the particle collector, the particle collecting means has a housing with a chamber accommodating a plurality of cylindrical rods. Each rod has an outer particle collecting surface. Alternate rods are connected to a high voltage power supply and ground to establish an electric field between adjacent rods. The charged particles flowing through the electric field are collected on the outer surfaces of the rods. Support means locate the rods in the housing chamber. The support means can be removed from the housing whereby the rods can be cleaned and repaired.

In a fourth embodiment of the particle collector, the chamber through which the particulate matter and exhaust gases flow is filled with a fibrous matrix, such as a plurality of filaments or fibrous elements. The charged particulate matter moves through the fibrous matrix and is deposited on the fibers and collector rods by the electric field. The advantage of this method is that the particles travel only a short distance before they are collected. The fibrous matrix is periodically removed and new fibrous matrix is installed.

In a fifth embodiment of the particle collector, a removable collecting cartridge is located within the collecting chamber. The cartridge has alternate electrically conductive plates which, when subjected to electric power, establishes the electric field for collecting the charged particulate matter. The entire cartridge can be removed from the collector for cleaning or replacement.

In the sixth embodiment of the particle collector, the particle collecting means are elongated cylindrical members that are concentrically located relative to each other to provide an electric field through which the particles flow. The cylindrical members are alternately connected to ground and to a source of high voltage. Each collector can be placed close to the engine and kept hot by thermo-insulation or other means. The particles collected on the plate, rods or cylindrical members are oxidized whereby the collector members are self-cleaning.

The method for controlling the amount of particulate matter discharged into the ambient air by a diesel engine or like combustion apparatus comprises the imparting of an electric charge on the particulate matter formed in the combustion area or chamber during the combustion of hydrocarbon fuel in the diesel engine. The diesel engine may have a plurality of combustion chambers receiving air and hydrocarbon fuel, i.e., diesel oil. Particles are electrically charged or imparted with an electrical charge during the formation of the particles in the combustion chambers of the diesel engine. The particle charge is bi-polar or both positive and negative. The charged particles, along with the hot exhaust gases of the diesel engine, are moved to a particle collector having particle matter collecting means. An electric field is established within the particle collector by ap-

plying a voltage to part of the collecting means. The voltage can be a D.C. voltage. Typically, several thousand volts are needed, the exact voltage being dependent upon the engine and collector size. The charged particles, along with exhaust gases, flow into the electric field. The charged particles are collected on the collecting means. The collected particles can be oxidized by exhaust gas heat from the engine. The collector can be located close to the engine and kept hot by thermo-insulating means. Oxidation of the collected particles makes the device self-cleaning. The applied electric field functions to deposit the particles on the collection surfaces for subsequent oxidation by exhaust gas heat from the engine.

The uncharged particles and exhaust gases flow through the electric field and are discharged to the atmosphere or to a catalytic converter. During the operation of the collector, deposits of particles are built up on the collection surfaces. These deposits will fracture from time to time. The resulting particles will either be re-entrained or fall to the bottom of the collector. The re-entrained particles are much larger than the sub-micron particles originally collected. The larger particles are easily removed by an inertial separator, scrubber, or other collection devices downstream of the collecting means. In some applications, the scrubber can be a water scrubber operable to cool exhaust gases, as well as collect the larger particles. The collected larger particles can be directed to a particle transfer and mixing unit that mixes these particles with the fuel for the engine.

IN THE DRAWINGS

FIG. **1** is a diagrammatic view of a means employing the method and apparatus of the invention for reducing the amount of particles emitted by a combustion system into the atmosphere;

FIG. **2** is a diagrammatic plan view of a diesel engine connected to a first particle collector;

FIG. **3** is an enlarged sectional view taken along the line **3—3** of FIG. **2**;

FIG. **4** is an enlarged foreshortened sectional view taken along the line **4—4** of FIG. **2**;

FIG. **5** is a side elevational view of a second modification of a means employing the method and apparatus of the invention for reducing the amount of particles emitted by a diesel engine into the atmosphere;

FIG. **6** is an enlarged sectional view taken along the line **6—6** of FIG. **5**;

FIG. **7** is a sectional view taken along the line **7—7** of FIG. **6**;

FIG. **8** is a top plan view of a third modification of a means employing the method and apparatus of the invention for reducing the amount of particles emitted by a combustion system into the atmosphere;

FIG. **9** is an enlarged sectional view taken along the line **9—9** of FIG. **8**;

FIG. **10** is an enlarged foreshortened sectional view taken along the line **10—10** of FIG. **8**;

FIG. **11** is an enlarged sectional view of a portion of FIG. **9** showing the connection between a rod and rod support plate;

FIG. **12** is a perspective view of a fourth modification of a particle collector useable with the means employing the method and apparatus of the invention for reducing the amount of particles emitted by a combustion system into the atmosphere;

FIG. **13** is an enlarged foreshortened sectional view taken along the line **13—13** of FIG. **12**;

FIG. **14** is a sectional view taken along the line **14—14** of FIG. **12**;

FIG. **15** is a foreshortened perspective view of the filter used in the collector of FIG. **12**;

FIG. **16** is a side view, partly sectioned, of an electrical connector used to connect the collector to a power supply;

FIG. **17** is a top plan view of a fifth modification of a particle collector useable with the means employing the method and apparatus of the invention for reducing the amount of particles emitted by a combustion system into the atmosphere;

FIG. **18** is a foreshortened sectional view taken along the line **18—18** of FIG. **17**;

FIG. **18** is a sectional view taken along the line **19—19** of FIG. **18**;

FIG. **20** is a foreshortened enlarged sectional view taken along the line **20—20** of FIG. **18**;

FIG. **21** is a perspective view of the replaceable collector cartridge used in the collector of FIG. **17**;

FIG. **22** is a perspective view of a fifth modification of a particle collector useable with the means employing the method and apparatus of the invention for reducing the amount of particles released by a combustion system into the atmosphere;

FIG. **23** is an enlarged, foreshortened, and longitudinal sectional view of the collector of FIG. **22**;

FIG. **24** is a sectional view taken along the line **24—24** of FIG. **23**;

FIG. **25** is a diagrammatic view of another means employing the method and apparatus of the invention for collecting particles exhausted from a combustion process and recycling the particles into the fuel used in the combustion process;

FIG. **26** is an enlarged sectional view taken along line **26—26** of FIG. **25**;

FIG. **27** is a sectional view taken along line **27—27** of FIG. **26**;

FIG. **28** is an enlarged sectional view taken along line **28—28** of FIG. **25**;

FIG. **29** is an enlarged sectional view taken along line **29—29** of FIG. **25**; and

FIG. **30** is a diagrammatic view of a modification of the method and apparatus of FIG. **25**.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. **1**, there is shown a diagrammatic view of the means indicated generally at **30** employing the method and apparatus of the invention for educing the amount of particulate matter or particles established as a result of combustion or hydrocarbon fuel into the atmosphere. A combustion apparatus **31**, as a diesel engine, has an air intake structure **32** operable to direct air, indicated by arrow **33**, to the combustion chamber or chambers of apparatus **31**. A fuel supply unit **34** functions to introduce fuel to the combustion chamber of combustion apparatus **31**. The combustion process produces heat, gases, and particles, as well as output energy. The particulate matter of particles are electrically charged as a result of their formation process. In other words, the electrical charge is established or imparted during the formation of the particles in the combustion process. The combustion of fuel, as hydrocarbon fuel, includes thermic oxidation or the air-fuel mixture. During this oxidation process, particles are formed

and electrical charges are generated along the flame front of the burning fuel. The electrical charges are associated with a majority of the particles. The particle charge is bi-polar or both positive and negative. The exhaust gases and particles are discharged from combustion apparatus **31** through exhaust structure **36**, as an exhaust manifold, having a passage **37**. The particulate matter is shown as positive and negative charged particles **38**. The charged particles **38**, along with the gases in passage **37**, flow to a particle collector **39**. Particle collector **39** is a precipitator employing a static electric field powered by high voltage power supply **41**. High voltage power supply **41** is a conventional high voltage solid state encapsulated module powered by a 12 volt D.C. power source and has an output of several thousand volts. Other types of high voltage power supplies and output voltage can be used to provide collector **39** with high voltage power. The charged particles **38**, as they move through an electric field in collector **31**, are deposited on collector structures, as plates, rods, sleeves, and the like. Particle collector **39** is in direct communication with exhaust structure **36** so that it receives hot gases along with the charged particles from combustion apparatus **31**.

Collector **39** can be located close to exhaust structure **36** to minimize charge leak-off from the charged particles and to insure that it receives maximum heat of the exhaust gases. Thermo-insulation can be used to prevent dissipation of heat from the exhaust structure **36** and tubular means connecting the exhaust structure to the particle collector **39**.

The collected particles that accumulate on the collector structures oxidize and form mostly CO_2. The oxidation of the collected particles makes the collector self-cleaning. The cleaned gases are discharged from collector **39** through an exhaust discharge pipe **42**. The exhaust gases **43** can be discharged into the atmosphere.

In another mode of operation, deposits of particles are built up on the collecting structures of collector **39**. Electrostatic and adhesion forces and particle affinity retain the particles on the collecting structures. The deposits of particles will fracture or break loose and re-entrain in the moving gases or fall to the bottom of collector **39**. Re-entrained particles are much larger than the sub-micron charged particles originally collected. These larger particles can be readily removed by a second particle collection device **44**, as an inertial separator, scrubber, or cyclone separator located downstream of collector **39**. For example, a water scrubber can be used with collector **39** to collect the re-entrained particles and cool the exhaust gases discharged into the atmosphere.

Referring to FIG. **2**, there is shown first means **45** employing the method and apparatus of the invention for reducing particulate matter or particles emitted by an internal combustion engine **46**. Engine **46** is a diesel engine having an air intake unit **47** and an exhaust manifold **48**. Conventional fuel injectors for introducing hydrocarbon fuels to the combustion chambers are part of engine **46**. Exhaust manifold **48** is connected to an exhaust pipe or conduit **49** which carries the discharged gases and charged particles **51** to a particle collector indicated generally at **52**.

Diesel engine exhaust particles consist mainly of roughly spherical carbonaceous nuclei which have grown by coagulation into chain aggregates. These particles are primarily elemental carbon, but may also contain significant quantities of absorbed or condensed hydrocarbons, hydrocarbon derivatives, sulfur compounds and other materials.

The particles emitted by diesel engine **46**, as a whole, are substantially neutral. The cloud of particles is neutral, as there are about as many positively charged particles as there are negatively charged particles. It has been determined that the individual particles in the cloud carry a significant electrical charge. A significant fraction of the particles emitted from diesel engine **46** are electrically charged. The charge distribution is substantially symmetrical and there are as many positively charged particles as there are negatively charged particles. The combustion of the hydrocarbon fuel injected into the compressed air in a cylinder or combustion chamber in a diesel engine is a complex process. It includes thermic oxidation along the flame front that moves across the combustion chamber. The particles are formed along the frame front and electrical charges are generated. The electrical charges are positive and negative and are associated with a majority of the particles. Tests of diesel engines have shown that from 72% to 88% of the particles by mass in the exhaust were electrically charged. The charge distribution was nearly symmetrical. There were as many positively charged particles as there were negatively charged particles. The percentage of particles that were electrically charged under different engine load conditions varied. At idel, the percentage was about 72%. At full load, the percentage was about 88%. The particles were found to become charged as a result of the combustion process occurring within the engine.

Particle collector **52** is a static electric field precipitator powered by high voltage power supply **53**. A high voltage power supply **53** of several thousand volts is coupled to a D.C. power source **53A**. Power supply **53**, connected to a 12-volt battery **53A**, includes an inverter **53B**, a step-up transformer **53C**, and a rectifier **53D**. Power supply **53** can be connected to the D.C. battery of a vehicle, as a car or truck. The voltage output of power supply **53** can vary in accordance with the requirements of the particle collecting process. For example, voltages as low as 100–200 volts or as high as 10,000 or more volts can be used. The voltages will vary with the size and type of diesel engine and particle collector, as well as the rate of flow of particles into the collector.

Collector **52** has first and second particle collecting surface means or electrodes that are spaced from each other and connected to the high voltage power supply and ground, respectively. A gas exhaust or discharge pipe **54** is connected to the outlet end of collector **52** to carry the emissions and the gases to a muffler or catalytic converter. A clamp **58** secures pipe **54** to collector **52**. Collector **52** operates to collect the particles on the first and second particle collecting surface means. The particles build up on the surface means. Electrostatic and adhesion forces and particle affinity forces retain the particles on the surface means and particles collected on the surface means. In time, the build up of particles on the surface means will fracture or break loose and re-entrain in the gas moving through collector **52**. The re-entrained particles are much larger in size than the sub-micron charged particles originally formed in the diesel engine combustion chambers. The large particles are readily removed by a particle collection device **44**, as an inertial separator or scrubber, located downstream of collector **52**. The collection device **44** is a secondary collection apparatus that can be a water

scrubber operable to collect the large particles and cool the exhaust gases.

Referring to FIGS. **3** and **4**, particle collector **52** has an elongated box shaped housing or casing **59** defining an elongated chamber **61**. Chamber **61** has a cross section size larger than the cross section of pipe **49**. Housing **59** comprises generally upright flat side walls **62** and **63** joined to a bottom wall **64**. The top of housing **59** has an elongated opening **66** closed with a cover **67**. A plurality of fasteners, as bolts **68**, secure cover **67** to top portions of side walls **62** and **63**. Bolts **68** can be removed so that the cover and structures attached to the cover can be separated from housing **59**.

A plurality of longitudinal upright first electrodes or plates **69** are located in chamber **61**. The bottom edges of plates **69** are secured to a flat horizontal base or plate **71**. Plates **69** are located in side-by-side spaced relation and extend from base **71** upwardly toward cover **67**. Base **71** is mounted on a plurality of blocks **72** which space the plate **71** above bottom wall **64**. A plurality of fasteners **73** extended through blocks **72** secure base **71** to bottom wall **64**. A line or electrical conductor **74** connects fasteners **73** and plate **71** to ground.

A plurality of second electrodes or plates **76** are located in chamber **61**. Plates **76** are generally flat rectangular members positioned between adjacent plates **69**. Plates **76** are attached to and extend downwardly from a flat top or support **77**. A plurality of blocks **78** of electrically insulative material, as glass, plastic, and the like, space plate **77** from cover **67**. Blocks **78** have upwardly directed cylindrical bosses **79** that project through holes **81** in cover **67**. C-clips **82** surround bosses **79** to secure blocks **78** to cover **67**. Other types of fastening structure, as nuts, pins, and clamps, can be used to attach blocks **78** to cover **67**. Electrically conductive bolts **83** extend through blocks **78** and mount plate **77** on blocks **78**. An electrically conductive line **84** connects bolts **83** to the high voltage power supply **53**.

Plates **76** are spaced an equal distance from the adjacent first plates **69**. The ends of plates **76** are spaced from base **71**. The upper ends of plates **69** are spaced below plate **77**. The spaces between the adjacent sides and ends of the plates **69** and **76** are substantially equal.

As shown in FIG. **3**, there are seven upwardly directed first plates **69** and six downwardly directed second plates **76**. Second plates **76** are located between adjacent first plates **69**. The plates **69** and **76** are metal electrical conductive members, such as stainless steel, aluminum, and the like, having generally flat particle collecting surfaces. Plates **69** and **76** can be made of any corrosive resistant electrically conductive material, including, but not limited to, metal, conductive ceramic, electrically conductive plastic, and plastic coated with an electrically conductive skin. The number and size of the plates **69** and **76** can vary. The six and seven plate arrangement shown in FIG. **2** is by way of example and not intended to limit the number, nor the size, of the particle collecting means having the particle collecting surfaces.

Referring to FIG. **4**, charged particles **51** flow through exhaust pipe **49** into an inlet or vestibule **61**A of large chamber **61**. The velocity of the gas and particles is decreased because of the increased size of chamber **61**. The gas and particles entrained in the gas flow through spaces **86** between adjacent plates **69** and **76**. The high voltage power source **53**, supplying several thousand volts to the plates, establishes an electric field between adjacent plates **69** and **76**. The charged particles **51** flowing through spaces **86** are attracted to and are collected on the surfaces of plates or electrodes **69** and **76** thereby removing the charged particles from the gas. The gas flows through outlet section **61**B of chamber **61** into the exhaust pipe **54**.

Particle collector **52** can be located close to the engine. Exhaust pipe **49** can be short and thermo-insulated so that the collector will receive hot gases and charged particles directly from the engine. The collected particles that accumulate on the particle collecting surfaces, when heated, will oxidize and form mostly CO_2. The oxidation of the collected particles makes the collector self-cleaning. The electric field in collector **52** is used to deposit the particles on the particle collection surfaces. The heat subsequently oxidizes the collected particles.

Referring to FIGS. **5–8**, there is shown a second modification of the means indicated generally at **87** employing the method and apparatus of the invention for reducing the amount of particulate matter emitted from a diesel engine **46**. Engine **46** has an exhaust structure **48** for carrying charged particles **51** and gas to a particle collector indicated generally at **88**. Collector **88** has an elongated housing or casing **89** surrounding an elongated particle collection chamber **91**. Housing **89** has a pair of upright side walls **92** and **93** joined to an inlet wall **94** and an outlet wall **97**. A clamp **96** secures a portion of wall **94** to the exhaust member **49**. A second clamp **98** attaches discharge pipe **99** to a portion of outlet wall **97**.

A pair of downwardly directed hoppers **101** and **102** are connected to the lower edges of side walls **92** and **93**. Hoppers **101** and **102** converge downwardly and are open to the particle collection chamber **91**. Hoppers **101** and **102** surround particle receiving passages **103** and **104** which are in communication with passages in downwardly directed necks **105** and **106**. A pair of short tubes **107** and **108** are mounted on necks **105** and **106**, respectively. Tubes **107** and **108** are joined to an elongated return tube or pipe **109**. As shown in FIGS. **5** and **7**, return pipe **109** connects passages **103** and **104** of hoppers **101** and **102** to air intake **47** of diesel engine **46**. Thus, particles from collector **88** and a limited amount of gas are recycled or fed back to the intake **47** of diesel engine **46**.

Housing **89** has a generally rectangular top opening **111** that is normally closed with a cover **112**. A plurality of fasteners **113**, as bolts or screws, secure cover **112** to side and end walls **92, 93, 94**, and **97**. Fasteners **113** can be removed so that cover **112** and structure secured to cover **112** can be separated from the housing for cleaning and repair.

Charged particle collecting means comprising a first plurality of collector electrodes or plates **114** having particle collecting surfaces are located in chamber **91**. As shown in FIG. **6**, plates **114** are located in parallel side-by-side positions and mounted on a plurality of transverse rods **116**. The spaces between adjacent plates **114** are open and in communication with passages **103** and **104** of hoppers **101** and **102**. Nut and bolt assemblies **117** secure rods **116** to the bottom parts of side walls **92** and **93**. Additional nuts **121** threaded on rods **116** engage opposite sides of each of the plates **114** to position the plates on rods **116**. Other structures can be used to locate and secure plates **114** to rods **116** or housing side walls **92** and **93**. An electrical conductor or line **118** connects the rods **116** and plates **114** to the ground.

A plurality of second electrodes or plates **122** having particle collecting surfaces are located in chamber **91**

and between adjacent plates **114**. Second plates **122** extend downwardly from and are attached to a generally horizontal support **123**. A plurality of electrically insulative blocks **124** space support **123** from cover **112** and locate the plates **122** in the spaces between adjacent first plates **114**. Blocks **124** have upright bosses **126** which project through holes **127** and cover **112**. C-clips **128** associated with bosses **126** secure blocks **124** to the cover **112**. Other types of structures can be used to attach blocks **124** to cover **112**. Each block accommodates a bolt **129** which secures the support **123** to the blocks **124**. Bolts **129** also function as electrical conductors to connect plates **122** to a line or conductor **131** leading to a high voltage power supply **132**, similar to power supply **53**. Power supply **132** is connected to a source of electrical power, as a D.C. battery.

In use, the particles and gases, including the charged particles **51**, flow into the inlet or vestibule portion **91A** of chamber **91**. The gas and particles flow through spaces **133** between the adjacent plates **114** and **122**. The high voltage power supply **132** establishes an electrical field between the adjacent plates **114** and **122**. The charged particles are collected on the surfaces of plates **114** and **122**. The collected or accumulated particles tend to agglomerate or merge. Electro-static and adhesion forces and particle affinity forces retain the collected particles on plates **114** and **122**. The larger groups of particles flake off or separate from the plates **114** and **122** because of vibration of the collector **88** and movement of gases between adjacent plates **114** and **122**. Other means, as periodic reverse polarity of the power supply, can be used to separate the collected particles from the plates **114** and **122**. The merged particles that are separated from plates **114** and **122** fall into hopper passages **103** and **104**. The inlet air intake **47** of the engine draws the particles and part of the gases through tube **109** back into the air intake of engine **46**. The particles flow back into the engine combustion chambers. The gases and uncharged particles flow from collector **88** through outlet chamber section **91B** and the passage and discharge pipe **99**. The gases can be delivered to a catalytic converter, secondary collector, or the atmosphere.

Referring to FIGS. **8–10**, there is shown a third modification of the particle collector indicated generally at **134**. A high voltage power source **136**, similar to power source **53**, is connected with line **137** to collector **134**. Collector **134**, as shown in FIG. **9**, has an elongated generally box shaped housing or casing **138** comprising a pair of upright side walls **139** and **141**. The side walls **139** and **141** are joined to a flat bottom wall **142**, an inlet end wall **143**, and an outlet end wall **144**. The walls **139**, **141**, **142**, **143**, and **144** surround a particle collection chamber **146**. The charged particles and exhaust gases are delivered to chamber **146** from engine **46** through discharge conduit or pipe **49**. A clamp **147** attaches a portion of inlet end wall **143** to pipe **49**. The outlet end wall **144** is joined to a discharge tube **148**. A clamp **149** surrounds tube **148** to secure tube **148** to a portion of discharge outlet end **144**.

The top edges of side walls **139** and **141** have outwardly directed flanges or lips **151** and **152**, respectively. A flat cover **153** closes the open upper end of housing **138** and rests on lips **151** and **152**. A plurality of fasteners **154**, as nut and bolt assemblies, attach cover **153** to lips **151** and **152**.

A first longitudinal plate **156** is located in chamber **146** adjacent the inside of wall **139**. Plate **156** has an inwardly directed upper flange or top flange **157**. Flange **157** engages a plurality of electrically insulative blocks **158** mounted on top wall **153**. The blocks **158** accommodate bolts **159** carrying nuts **161**. Bolts **159** are attached to flange **157** to secure the flange **157** to blocks **158**. Plate **156** carries a plurality of rows of horizontal first electrodes or rods **162**. The rods **162** are cylindrical members having particle collecting surfaces and extend from plate **156** toward a second plate **164** located adjacent the inside of side wall **141**. Referring to FIG. **11**, rod **162** has a threaded end **163** threaded into an opening in plate **156**. The rod **162** can be attached with other means to plate **156**.

Second plate **164** has an inwardly directed top flange **166** spaced from the inside of cover **153** with a plurality of electrically insulative blocks **167**. Blocks **167** are mounted on or attached to cover **153**. Bolts **168** extended through blocks **167** are attached to flange **166**. Nuts **169** threaded onto bolts **168** hold flange **166** and blocks **167** in assembled relation. Plate **164** carries a plurality of rows of second electrodes or rods **171**. The rods **171** located parallel to rods **162** have particle collecting surfaces and are spaced in rows that are intermediate the rows of rods **162**. The rectangular pattern of the rods **162** and **171** are equally spaced from each other so that there is a substantially equal electrical field between the rows of rods **162** and **171**. Plate **156** is connected with a line **172** to ground. Line **137** from high voltage power source **136** is connected to plate **164** via the volts **168**. High voltage power source **136** operates to establish an electrical field between the adjacent rows of rods **162** and **171**. The charged particles **51** flow through passage **146** and through the electric field between the adjacent rows of rods **162** and **171**. The charged particles are collected on the particle collecting surfaces of rods **162** and **171**. Electro-static and adhesion forces and particle affinity forces retain the collected particles on rods **162** and **171**. The exhaust gas and neutral particles flow through the outlet region **146B** of the chamber and through the passage of discharge pipe **148**. Heat from the engine can oxidize the particles collected on the particle collecting surfaces of rods **162** and **171**.

Cover **153** is removable from housing **138** by removing nut and bolt assemblies **154**. When cover **153** is removed, both plates **156** and **164**, along with rods **162** and **171** attached thereto, are removed from the housing. Plates **156** and **164** and rods **162** and **171** can be cleaned of particles. The cleaned rods and plates **156** and **164** are returned to the chamber **146** as a unit.

Referring to FIGS. **12**, **13**, and **14**, there is shown a fourth modification of the particle collector indicated generally at **173** useable with engine **46** for reducing the amount of particulate matter discharged into the atmosphere. Collector **173** has an elongated box-like housing or casing **174** comprising upright side walls **176** and **177**. Walls **176** and **177** are joined to a generally flat bottom wall **178**, an inlet end wall **179**, and an outlet end wall **182**. Inlet end wall **179** is attached with a clamp **181** to the engine outlet pipe **49**. Outlet end wall **182** is joined to an exhaust pipe **183** with a clamp **184**. The walls **176–179** and **182** surround a particle collection and filtering chamber **185**.

The top portions of side walls **176** and **177** have outwardly directed lips **186** and **187** supporting a cover **188**. The cover **188** closes the top of chamber **185** and is attached to lips **186** and **187** with a plurality of fasteners

189, as nut and bolt assemblies. Other types of fasteners can be used to connect cover 188 to lips 186 and 187.

As shown in FIG. 14, a base or bottom plate 191 is supported on bottom wall 178 with a plurality of blocks 192. A plurality of bolts 193 extended through blocks 192 attach plate 191 to blocks 192 and bottom wall 178. A line 194 connects bolts 193 to ground. A plurality of rows of upright cylindrical electrodes or rods 196 having particle collecting surfaces are attached to plate 191. The number of rods in each row of rods varies according to the length of the housing 174. As shown in FIG. 13, rods 196 are equally spaced from each other and extend the full length of chamber 185. Five rows of rods 196 are illustrated in FIG. 13.

A second or top plate 197 is located in chamber 185 adjacent cover 188. A plurality of electrically insulative blocks 198 mount plate 197 on cover 188. Bolts 199 extended through blocks 198 are attached to plate 197 and a high voltage power supply 201 with a line 202. A high voltage power supply 201, similar to power supply 53, is coupled to D.C. power.

Referring to FIG. 16, there is shown a means for releasably connecting line 202 to bolt end 199. A connector or cap 203 is threaded onto upper end of bolt 199. Cap 203 has an end with a longitudinal bore 204. Line 202 has an elongated finger or terminal 206 that extends into bore 204. Other types of electrical connections can be used to releasably connect line 202 to the bolts 199.

A plurality of rows of downwardly directed cylindrical second electrodes or rods 207 having particle collecting surfaces are attached to top plate 197. As shown in FIG. 13, rods 207 are located in rows that are located between adjacent rows of the first rods 196. Each second rod 207 is equally spaced from an adjacent first rod 196 so that there is a substantially equal electric field established by the electrical potential difference between rods 196 and 207 throughout chamber 185.

A filter element 208 is located in chamber 185. As shown in FIG. 15, filter element 188 has a plurality of vertical holes 209 for accommodating the rods 207. The bottom side of filter 208 has similar holes (not shown) for accommodating rods 196. Filter element 208 is a filament or fiber filter made of non-conductive filaments, such as plastic fibers. Other types of non-electrically conductive material can be used for filter element 208. Filter element 208 provides surfaces on which the particulate matter moving through chamber 185 can impinge and collect. Filter 208 is removable from chamber 185 for servicing and replacement. The top cover 188 is removed from housing 174. The filter element 208 is pulled upwardly through the open top of housing 174.

Particle collector 173 can be used as a static electric field precipitator with filter element located in chamber 185. Particles 51 and exhaust gas move through the inlet portion 185A of the chamber 185 and through the electric field established between rods 196 and 207 and the filter 208. The charged particles are collected on the filter fibers and surfaces of rods 196 and 207. Additional non-charged particles are collected on the filter filaments 208. The gas and particles that are not collected move through outlet section 185B of the chamber 185 into discharge pipe 183. Particle collector 173 can be used as a static electric field precipitator without filter element 208.

Referring to FIGS. 17, 18, and 19, there is shown a fifth modification of the particulate matter collector indicated generally at 211 used with engine 46. Collector 211 is attached to engine exhaust pipe 49 with a clamp 212 to receive the exhaust gases and particles discharged by the engine. The discharge end of collector 211 is attached to a pipe or tube 213 with a clamp 214. Collector 211 has an elongated generally box shaped housing or casing indicated at 216 surrounding a particle collection chamber 223. Housing 216 has a pair of upright elongated side walls 217 and 218 joined to a generally flat bottom wall 219. Walls 217–219 are connected to an inlet wall 221 surrounding the inlet portion 223A of chamber 223. The opposite end of housing 216 has an outlet end wall 222 surrounding the outlet section 223B of the chamber 223.

Referring to FIG. 19, the top portions of side walls 217 and 218 have outwardly directed lips 224 and 226 providing support for a cover or door 227. As shown in FIG. 18, end walls 221 and 222 are provided with top lips 221a and 222A, respectively, for receiving the ends of cover 227. Returning to FIGS. 17–19, an elongated piano type hinge 228 pivotally connects cover 227 to lip 224 allowing cover 227 to be pivoted or moved upwardly to an open position to provide access to chamber 223. A pair of releasable fasteners 229, as nut and bolt assemblies having wing nuts, releasably hold cover 227 in its closed position. Fasteners 229 are pivotally mounted on lip 226. Wing nuts clamp over 227 onto lip 226. A generally flat seal 230 cooperates with lips 224, 226, 221A, and 222A, and the outer peripheral edge of cover 227 to prevent the escape of exhaust gases and particulate matter from chamber 223 through the top of housing 216.

A particle collecting cartridge indicated generally at 231 is located in chamber 223. The cartridge is a self-contained unit that can be removed from chamber 223 for servicing or replacement. Referring to FIGS. 19 and 21, cartridge 223 is an elongated tubular or box shaped unit having upright rectangular side walls 232 and 233 joined to bottom wall 234 and top wall 235. The ends of the cartridge are open so that exhaust gas and particles can flow through the cartridge. A pair of first electrodes or plates 236 and 237 having particle collecting surfaces are secured and extended between top wall 235 and bottom wall 234. Plates 236 and 237 extend the full length of top and bottom walls 235 and 234. Plates 236 and 237 divide the passage of the cartridge into three substantially equal passageways. Plates 236 and 237 have downwardly directed electrical connecting legs 236A and 237A, respectively. Walls 232, 233, 234, 235, and plates 236 and 237 are electrically conductive members, such as metal, electrically conductive ceramic, plastic members coated with electrically conductive materials, aluminum, and the like.

Three rectangular upright second electrodes or plates 238, 239, and 240 having particle collecting surfaces are located in the passages formed by the plates 236 and 237. Plates 238 and 239 are equally spaced from adjacent side walls 232 and 233 and plates 236 and 237 and extend the full length of the cartridge. Plates 238, 239, and 240 are electrical conductors, as sheet metal, stainless steel, aluminum, and the like. The upper and lower edges of plates 238, 239, and 240 are mounted in electrical insulator strips 241 secured to the bottom and top walls 234 and 235, respectively.

As shown in FIG. 18, the left end of cartridge 231 rests on a transverse support 242. Support 242 is an electrically insulative member having a conductor bar 243. Conductor bar 243 is electrically coupled to legs 236A and 237A with suitable connectors, such as U-

clips. Bolts **244** extended through support **242** are connected to conductor bar **243** and a line **246** leading to ground.

The right end of cartridge **231** engages a transverse support **247**. As shown in FIG. **20**, support **247** is an electrically non-conductive material, such as plastic, carrying a conductor bar **248** attached to bolts **249**. A U-shaped electrical connector or clips **250**, located in recesses **251**, are secured to the top of bar **248**. Clips **250** engage opposite sides of the plate legs **238A**, **239A**, and **240A** to electrically connect the plates **238**, **239**, and **240** to a high voltage power supply **254**. As shown in FIG. **18**, high voltage power supply **254** is connected to a line **253** leading to the bolts **249**.

Cartridge **231** is held in engagement with the supports **242** and **247** with cover **227**. A rectangular resilient cushion or pad **252** is interposed between cover **227** and top wall **235** of the cartridge. When cover **227** is in the closed position, pad **252** biases cartridge **231** in a downward direction thereby retaining connector legs **236A**, **237A**, **238A**, **239A**, and **240A** in electrical connection with clips **250**. The cartridge plates **236–240** can be provided with female or U-shaped electrical connectors. The male prongs or fingers can be mounted on plates **243** and **248** to provide for a releasable electrical connection between the cartridge **231** and plates **243** and **248**.

In use, high voltage power supply **254**, similar to power supply **53**, supplies an electrical potential to plates **238**, **239**, and **240**. This establishes an electrical field between plates **238**, **239**, and **240** and side walls **233** and **234** and first plates **236** and **237**. The charged particles **51** flow through passages between adjacent plates and side walls. The charged particles, because of the electrical field, are deposited on the collecting surfaces of plates **236–240** and the inside of side walls **232** and **233**. The exhaust gases and non-charged particles pass through the collector and are discharged to the catalytic converter, a secondary collecting device, or the atmosphere via discharge pipe **213**. Plates **236–240** can be subjected to heat from the engine. This will oxidize the particles collected on the collecting surfaces of plates **236–240**.

Cartridge **231** can be serviced by opening cover **227**. Cartridge **231** is removed upwardly from chamber **223**. A new cartridge can be readily inserted into the chamber and electrically connected to the bars **243** and **247**. When cover **227** is closed, pad **252** holds cartridge **231** in an operative electrically connected position in chamber **223**.

Referring to FIG. **22**, there is shown a sixth modification of the particle matter collector indicated generally at **300** useable with engine **46** for reducing the amount of particles discharged into the atmosphere. Collector **300** is an elongated cylindrical structure that is connected to a high voltage power supply **301** with a line **302** and ground. The collector **300** has a cylindrical housing or casing **303** including at one end an inlet end wall **304**. A short sleeve **306** is joined to the midsection of end wall **304** to accommodate the engine discharge or exhaust gas pipe or manifold structure. The opposite end of housing **303** has an outlet end wall **307** having a sleeve **308**. Sleeve **308** has an outlet passage for the gases and materials discharged from collector **300**. Housing **303** surrounds an elongated cylindrical chamber **309**. First collector means **310** is located within chamber **309**. First collector means **310** includes an elongated cylindrical rod **312** located generally along the longitudinal axis of chamber **309**. Collector means **310** also includes one or more cylindrical sleeves **311** concentrically located about rod **312** and concentric relative to each other. A plurality of second particle collector means **313** are associated with the first collector means **310**. The second collector means **313** are elongated cylindrical members concentrically located about the center rod **312** and cylindrical member **311**. The second collector means **313** are interspersed alternately with the first collector means **311**.

A plurality of rods or bolts **314** connect the first collector means **311** to ground. Insulator sleeves **316** disposed about the rods **314** electrically insulate the second connector means **313** from rods **314**.

The opposite ends of the cylindrical collector means **311** and **313** are supported on a plurality of second rods **317**. Rods **317** are in electrical connection with the second cylindrical collector means **313** and line **302** leading to the high voltage supply **301**. Electrical insulator sleeves **318** insulate the rods **317** from first collector means **311** and rod **312**. Other types of structures can be used to concentrically locate the first and second cylindrical collector means in a concentric alternate relation relative to each other in chamber **309**. The cylindrical collector means **313** are spaced from each other and provide cylindrical passages **309A**, **309B**, **309C**, and **309D**. The number of passages can be changed by either increasing or decreasing the number of first and second cylindrical collector means that are located in chamber **309**.

In use, high voltage power supply **301** supplies an electrical potential to the cylindrical collector means **311** and **313** and the center rod **312**. This establishes an electrical field between adjacent cylindrical collector means and housing **303**. The charged particles **51** move through the passages **309A–309D**. The charged particles, because of the electric field, are deposited on the surfaces of the cylindrical collectors **311** and **313** and the inside of housing **303**. The exhaust gases and non-charged particles pass through the chamber **309** and are discharged through sleeve **308**. The particles moving through sleeve **308** can be directed to a catalytic converter, the atmosphere, or a centrifugal separator operable to remove the particles from the carrier gas. Sleeve **306** can be mounted in close proximity to the discharge manifold of engine **46**. The hot gases emitted from the engine **46** will oxidize the collected particles on the cylindrical collector means **311** and **313**. The oxidized particles are converted into a gas, as CO or CO_2, which is discharged from collector **300** via sleeve **308**.

Referring to FIG. **25**, there is shown a means indicated generally at **400** employing the method and apparatus of the invention for reducing particulate matter or particles emitted by a combustion means, as an internal combustion engine indicated generally at **401**. Engine **401** is a diesel engine having a block **402** accommodating conventional pistons and a crank shaft connected to the pistons with connecting rods. Air supplied to the combustion chambers of the engine flows through an air intake unit **403** and an air intake manifold. Fuel injectors or nozzles **404** function to sequentially introduce hydrocarbon fuels, as diesel fuel, into the combustion chambers of engine **401**. A pump **406** operates to deliver liquid fuel under pressure to the fuel injectors **404**. Pump **406** is connected with a fuel supply line **407** and fuel return line **408** to a tank **410** for storing the diesel fuel. A valve **408A** is in line **408** to control the flow of fuel therein back to tank **410**. Engine **401** has an exhaust

manifold **409** having a passage **411** for carrying the exhaust gases and charged particles **412** to a particle collector indicated generally at **413**. The diesel engine exhaust particles **412** have the charge characteristics of the particles emitted by diesel engine **46** hereinbefore described.

Particle collector **413** can have the details of the particle collectors, as shown in FIGS. **3**, **9**, **18**, and **23**. The collector **413** is a static electric field precipitator powered by a high voltage power supply **414**. Power supply **414** is coupled to a D.C. power source **416**, as a vehicle 12-volt battery. A line **417** connects power supply **414** to conductor connectors **418** of particle collector **413**.

The discharge end of particle collector **413** has an outlet tube or sleeve **419** connected to a cyclone separator indicated generally at **421**. Separator **421** is a collection device operable to remove the particles that flow from collector **413**. Collector **413** operates to collect the particles on its particle collecting surfaces on the spaced electrodes in the collector **413**. The electrodes can be spaced plates, rods, or cylindrical members, as shown in FIGS. **3**, **9**, **19**, and **23**. The particles, as they are collected, build up on the surfaces. In time, the buildup of particles on the surfaces will fracture or break loose and re-entrain in the gas moving through collector **413**. The re-entrained particles are much larger in size than the sub-micron charged particles originally formed in the diesel engine combustion chamber. Vibrators, mechanical devices, and means to remove particles from the particle collection surfaces can be used to clear particles from the particle collection surfaces. The large particles are readily removed from the exhaust gases by cyclone separator **421**. Other types of particle separating devices can be used in lieu of cyclone separator **421**.

A cyclone separator, as shown in FIGS. **25**, **26**, and **27**, has a tubular body **422** surrounding a separation chamber **423**. An inlet means or manifold **424** is joined to one side of body **422** providing a tangential inlet passage **426** that extends generally tangential to cylindrical chamber **423**. A discharge tube or sleeve **427** secured to the top or end wall of body **422** extends into chamber **423**. Sleeve **427** has an outlet passage leading to the atmosphere for carrying exhaust gases. The outlet passage has an open end **429** that is located in approximate mid-section of chamber **423**. The lower end of body **422** has a particle exit opening **431** surrounded by a downwardly tapered or cone-shaped bottom **432**. A baffle **433** is located in chamber **423** above exit opening **431**. Baffle **433** has a slight convex or disc shape and is spaced from the inside wall of body **422** providing an annular passage for movement of the separated particles to exit opening **431**. The exhaust gas and particles carried by the gas enter the upper portion of chamber **423** and move in a spiral flow of main vortex downward between the walls of sleeve **427** and body **422** toward bottom baffle **433**. The flow then reverses its direction forming a vortex core which travels to the gas outlet passage **428**. Inertial separating forces acting on the particles cause the particles to move to exit opening **431**.

As shown in FIG. **25**, a particle transfer means indicated generally at **434** receives particles from cyclone separator **421** and dispenses the particles into the fuel flowing in line **407** to pump **406**. Particle transfer means has a fuel and particle mixing unit **436** connected to a particle inlet tube **437** leading to particle exit opening **431** of separator **421**. A fuel inlet tube **438** connects mixing unit **436** with fuel line **407**. A pump **439** driven

by an electric motor is connected to line **438** and moves fuel through line **438** into unit **436**. A fuel outlet tube **440** connects the outlet end of mixing unit **436** to fuel line **407**. Lines **438** and **440** connect the mixing unit **436** in parallel relation with fuel line **407** and do not interfere with the flow of fuel in line **407**. The level of fuel in mixing unit **436** is controlled with a pipe extended up into unit **436**. Other types of fuel level controls can be used to regulate the level of fuel in units **436**.

As shown in FIGS. **28** and **29**, fuel and particle mixing unit **436** has a housing **443** having a mixing chamber **444** where particles are mixed with fuel to form a colloidal suspension. A first connector **446**, as shown in FIG. **28**, connects the particle inlet tube **437** to the top of housing **443**. A second connector **447** connects fuel inlet tube **438** to housing **443**. A third connector **448** connects fuel outlet tube **440** to the end of housing **443**. Outlet tube **440** can be connected to fuel tank **408** so that the fuel particle mixture is delivered back to the tank and mixed with the fuel therein. Inlet tube **438** can be connected to a return fuel line **408** connecting pump **406** to tank **408** so that pump **406** moves fuel through chamber **444** and back to tank **408**.

A mixing assembly indicated generally at **449** is located within chamber **444** for mixing the particles directed into chamber **444** with the fuel flowing through chamber **444**. Mixing assembly **449** has a body **451** having an end **452** located in and closing the open end of chamber **444**. Nut and bolt assemblies **453** secure body **451** to housing **443**. A rotatable member **454** is rotatably mounted in end **453**. A helical mixing means **456**, shown as a coil or helical rod, is located in chamber **444** and connected to rotatable member **454**. A motor **457** drives rotatable member **454** thereby turning mixing means to mix the particles with the fuel flowing in chamber **444**. Motor **457** can be an electric motor connected to the electrical system of a vehicle. Motor **457** can be connected to the ignition switch of the vehicle so that it operates when the ignition switch is on. Motor **457** can be a fluid motor operable in response to the flow of the fluid in fuel line **407** or a source of fluid under pressure, as oil pressure. A cap **458** retains motor **457** on body **451**. A line **459** connected to housing **443** is open to chamber **444** to carry air from an air pressure source **461** to chamber **444**. The air moves through chamber **444** and into cyclone separator **421**.

In use, diesel engine **401** in operation discharges gas and particulates to exhaust manifold **407**. The particles, including charged particles, are directed to the particle collector **413**. The electrostatic field established in collector **413** by the electrodes separate the charged particles from the gases. The charged particles collect on the electrodes and agglomerate or form into larger particles. The larger particles, in use, are re-entrained with the gas and carried to separator **421**. Vibrators or mechanical devices can be used to facilitate removal of collected particles from the electrodes of collector **413**.

Separator **421** functions to separate the larger particles from the exhaust gas and discharge the gas to the atmosphere. The separated particles flow from separator **421** through particle inlet tube **437** to particle transfer means **434**. The particles flow into chamber **444** and are mixed with the fuel flowing through chamber **444** to form a colloidal suspension. The rotating helical means **456** mechanically mixes the particles with the fuel. Pump **439** continuously supplies fuel to chamber **444** so that the mixing of particles with the fuel is a continuous process. Pump **439** can be turned on and off to intermit-

tently mix particles with fuel or provide a batch process. The particles are entrained with the fuel and flow back into fuel line **407**. The particles being relatively small do not interfere with the operation of pump **406**, nor the fuel injectors **404**. The fuel injectors **404** inject the fuel and particles back into the combustion chambers where the combustion process is repeated.

Referring to FIG. **30**, there is diagrammatically shown a means indicated generally at **500** employing the method and apparatus of the invention for reducing particulate matter or particles emitted by combustion means, as an internal combustion engine. The engine is a diesel engine, as diagrammatically shown in FIG. **25** at **401**. The diesel engine is connected to a particle collector, such as a particle collector shown in FIGS. **3**, **9**, **18**, and **23**. The discharge end of the particle collector is connected with a sleeve **502** to a means to separate particles from the gas, such as cyclone separator **501**. Separator **501** is a particle collection device operable to remove particles that flow with the gas from the collector. Cyclone separator **501** has a gas outlet tube **503** and a particle outlet tube **504**.

A particle transfer means indicated generally at **506** is connected to tube **504** to receive the particles from separator **501**. Particle transfer means **506** has a housing **507** having a chamber **508**. Diesel fuel **509** located in chamber **508** is mixed with particles flowing or dispensed therein from separator **501**. A rotatable paddle or wheel **511** driven by motor **512** mechanically circulates the fuel in chamber **508** and mixes the particles with the fuel to form a colloidal suspension.

A first pump **513** connected to an inlet line **514** operates to deliver fuel from a fuel tank **516** to chamber **508**. Pump **513** can be driven by an electric motor connected to the electrical system of the vehicle. A second pump **517** connected in the return line **518** operates to pump fuel from chamber **508** back to tank **516**. Line **518** is connected to an upright fuel leveling pipe **519** that operates to regulate the level of the fuel in chamber **508**. Other types of fuel leveling devices can be used to maintain a supply of fuel in chamber **508**. Fuel lines **514** and **518** are connected directly to tank **516**. Particle transfer means **506** is not connected to fuel lines **521** and **522**. Main fuel supply line **521** and fuel return line **522** are connected to the pump used to supply fuel under pressure to the fuel injectors of the engine. The particles mixed with the fuel in chamber **508** are delivered back to the tank **516** and mixed with the fuel therein. In some structural arrangements, separator **501** can be located above tank **516** so that the particles from the separator are dispensed directly into the fuel in the tank. The particles are carried by the fuel supply line **521** to the pump connected to the fuel injectors of the engine.

While there has been shown and described the preferred embodiments of the apparatus employing the method for reducing the amount of particles released by a combustion system, including a diesel engine, it is understood that changes in the structure, including the particle collector, power supply, materials, and sizes of the parts can be made by those skilled in the art without departing from the invention. The invention is defined in the following Claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of reducing the amount of particles emitted by a combustion apparatus comprising: forming particles during combustion of hydrocarbon fuel and air in a combustion chamber of a combustion apparatus, imparting electrical charges on a substantial portion of the particles that are formed during said combustion during said imparting of electrical charges on the particles a substantially equal number of particles are positively charged and negatively charged whereby the particles as a whole are a substantially electrical neutral mass of particles, moving the charged particles with combustion gas directly from the combustion apparatus to a particle collector without an intermediate particle charging step whereby the charge on the particles remains substantially the same, said particle collector having particle collecting means, establishing an electric field by applying a voltage to the particle collecting means, and moving the charged particles without substantially changing the electrical charges on the particles into the electric field to collect at least some of the charged particles on the particle collecting means, said particles collected on the particle collecting means separating from the collecting means as large particles, moving said large particles with said gas from said particle collecting means, collecting said large particles that become separated from the particle collecting means, and introducing said collected large particles into the hydrocarbon fuel for the combustion apparatus.

2. The method of claim **1** wherein: the electrical charges on the particles are imparted during the combustion of hydrocarbon fuel and air in a diesel engine and the collected large particles are mixed with the fuel for the diesel engine.

3. The method of claim **1** wherein: said collection means have first collecting means and second collecting means, said voltage being applied to the first collecting means whereby opposite charged particles are collected on the first and second collecting means, respectively, said collected particles separating as large particles from the first and second collecting means.

4. The method of claim **3** wherein: the electrical charges on the particles are imparted during the combustion of hydrocarbon fuel and air in a diesel engine.

5. The method of claim **1** including: mixing said collected large particles with said fuel.

6. A method of reducing the amount of particles emitted by a diesel engine having a combustion chamber comprising: imparting electrical charges on particles within the combustion chamber formed during the combustion of hydrocarbon fuel and air in the combustion chamber of the diesel engine, during said imparting of electrical charges on the particles a substantially equal number of particles are positively charged and negatively charged whereby the particles as a whole are a substantially electrical neutral mass of particles, discharging the charged particles and exhaust gases from the combustion chamber of the diesel engine directly to a particle collector without an intermediate particle charging step whereby the charge on the particles remains substantially the same, said particle collector having particle matter collecting means without substantially changing the electrical charges on the particles, establishing an electric field by applying a voltage to the particle collecting means, moving the charged particles without substantially changing the electrical charges on the particles to the particle collecting means, moving the charged particles without substantially changing the electrical charges on the particles and exhaust gases into the electric field to collect a substantial portion of the charged particles on the particle collecting means, allowing the exhaust gases and uncol-

lected particles to flow through the particle collector, said particles collected on the particle collecting means separating as large particles, moving said large particles with said gas from said particle collecting means, collecting said large particles that become separated from the particle collecting means, and introducing said collected large paticles into the hydrocarbon fuel for the diesel engine.

7. The method of claim **6** wherein: said particle collection means having first collecting means and second collecting means, said voltage being applied to the first collecting means whereby opposite charged particles are collected on the first and second collecting means, respectively, said collected particles separating from the first and second collecting means.

8. The method of claim **6** including: mixing said collected large particles with said hydrocarbon fuel.

9. A method of removing at least some of the particles formed in a combustion chamber of a diesel engine during a combustion process within said chamber from the exhaust gas of the diesel engine, some of which particles have acquired positive charges and some of which have acquired negative charges during the com-

bustion process taking place within the combustion chamber of the diesel engine whereby the particles as a whole are a substantially electrical neutral mass of particles, the method comprising: transferring the exhaust gas and charged particles from the diesel engine directly to a particle collector without an intermediate particle charging step whereby the charge on the particles remains substantially the same, said particle collector having spaced electrodes of opposite polarity, passing said gas and charged particles between the spaced electrodes of opposite polarity and having a sufficient electric potential therebetween so that at least some of the charged particles are removed from the exhaust gas and collected on said electrodes, said particles collected on the electrodes separating as large particles, moving said large particles with said exhaust gas from said electrodes, collecting said large particles that become separated from the electrodes, and introducing said collected large particles into the hydrocarbon fuel for the diesel engine.

10. The method of claim **9** including: mixing said collected large particles with said hydrocarbon fuel.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,338,784
DATED : July 13, 1982
INVENTOR(S) : Benjamin Y. H. Liu et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 52, "educing" should be --reducing--.

Column 4, line 62, "of" should be --or--.

Column 12, line 18, "221a" should be --221A--.

Signed and Sealed this

Fifteenth Day of *February 1983*

[SEAL]

Attest:

GERALD J. MOSSINGHOFF

Attesting Officer *Commissioner of Patents and Trademarks*

Exhibit 7

US005980343A

United States Patent [19]

Rolinski

[11] Patent Number: 5,980,343

[45] Date of Patent: Nov. 9, 1999

[54] **EXHAUST SYSTEM FOR MARINE VESSELS**

[75] Inventor: **Adam Rolinski**, West Olive, Mich.

[73] Assignee: **S2 Yachts Inc.**, Holland, Mich.

[21] Appl. No.: **09/030,210**

[22] Filed: **Feb. 25, 1998**

Related U.S. Application Data

[60] Provisional application No. 60/040,039, Mar. 5, 1997.

[51] **Int. Cl.**[6] **B63H 21/32**

[52] **U.S. Cl.** **440/89**

[58] **Field of Search** 440/38, 46, 47, 440/88, 89

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,371,645	3/1968	Ward	440/89
4,019,456	4/1977	Harbert	440/89
4,509,927	4/1985	Ikeda .	
5,078,631	1/1992	Harbert .	
5,505,644	4/1996	Ousley, II et al. .	
5,700,172	12/1997	Ousley, II et al. .	

OTHER PUBLICATIONS

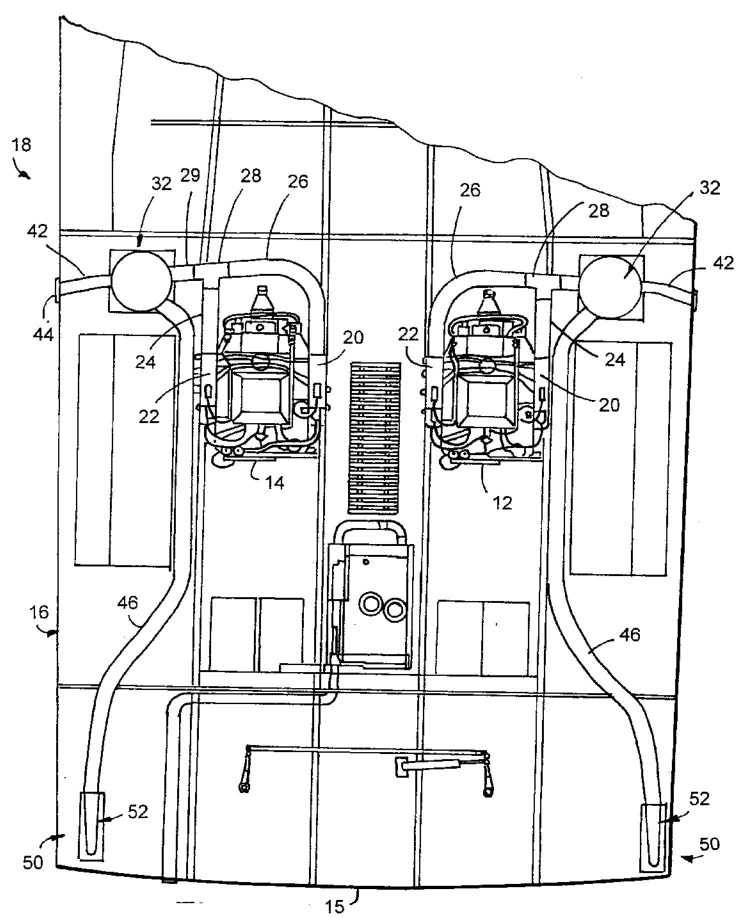
Exhibit A—Photographs 1, 2 and 3.

Primary Examiner—Stephen Avila
Attorney, Agent, or Firm—Price, Heneveld, Cooper, DeWitt & Litton

[57] **ABSTRACT**

A two pathway exhaust and water discharge through-hull system is coupled to a muffler for separating exhaust gases and cooling water at operating speeds such that at low engine speeds exhaust gases and water are discharged through a first outlet preferably above the waterline and, when the engine speed is increased above a predetermined level, exhaust gases are discharged through a second outlet which communicates with a streamlined, low back-pressure underwater discharge skeg and water is discharged through the first outlet. In a preferred embodiment of the invention, a discharge skeg is positioned at each comer of the transom for a twin engined vessel. In a preferred embodiment also, each of the underwater discharge skegs is mounted to the bottom of the hull and includes a mounting flange and an upwardly extending collar which extends through the hull and is coupled to an adapter for coupling the discharge skeg to an exhaust outlet of a muffler. As a result, an exhaust system is provided which is efficient, quite and which discharges exhaust gases underwater and away from the vessel when underway at normal operating speeds.

24 Claims, 5 Drawing Sheets



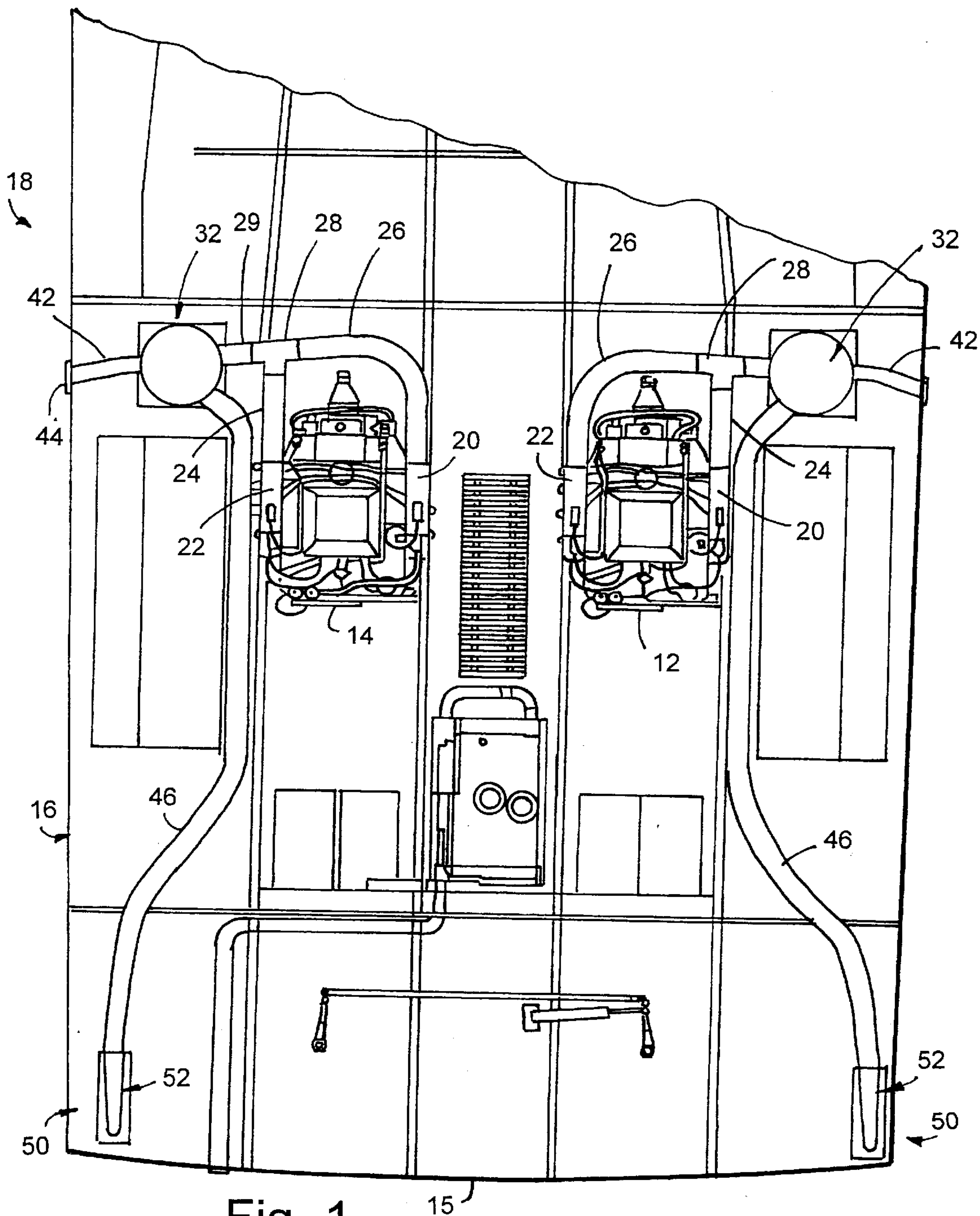

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Fig. 1

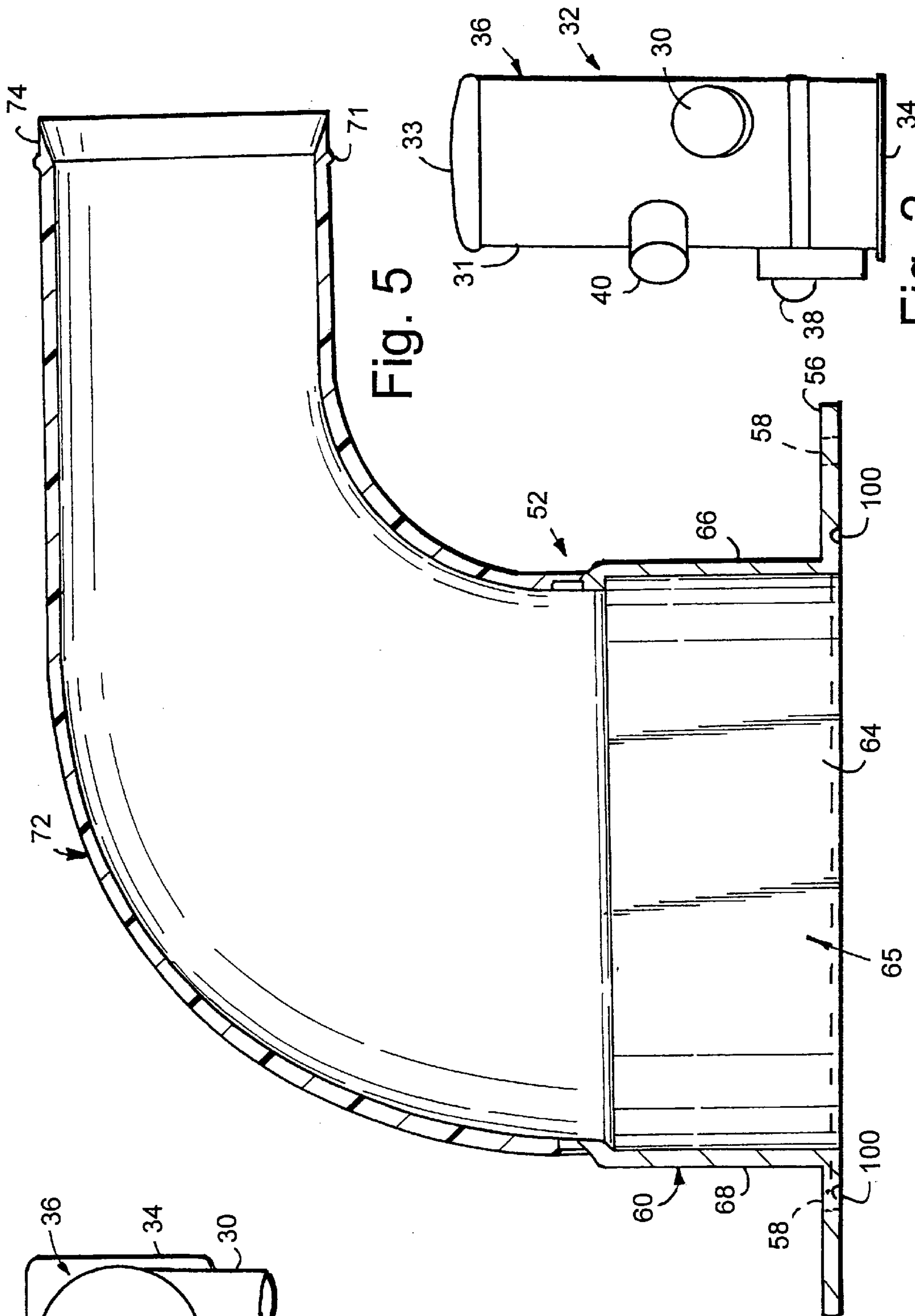

Fig. 5

Fig. 2

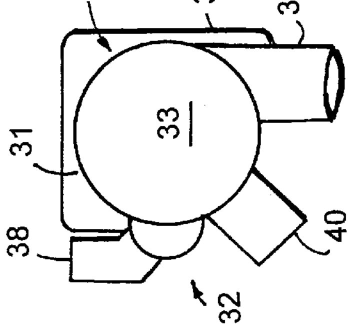

Fig. 3

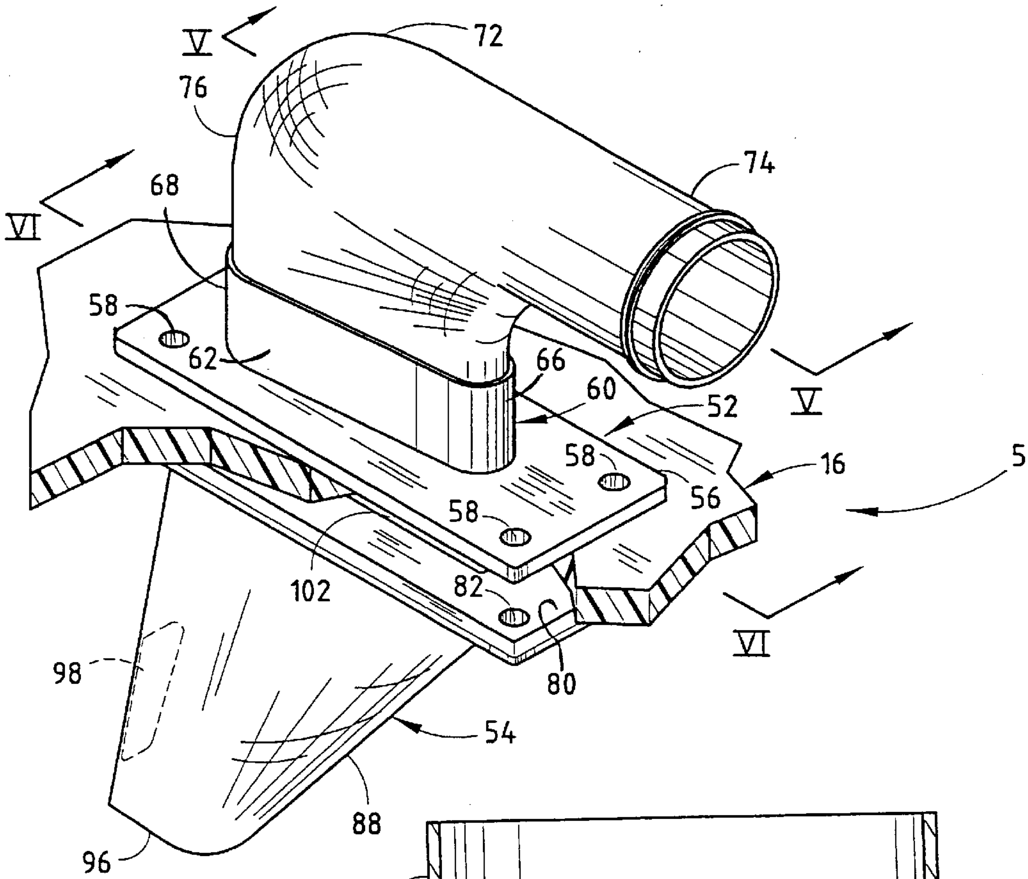
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FIG. 4

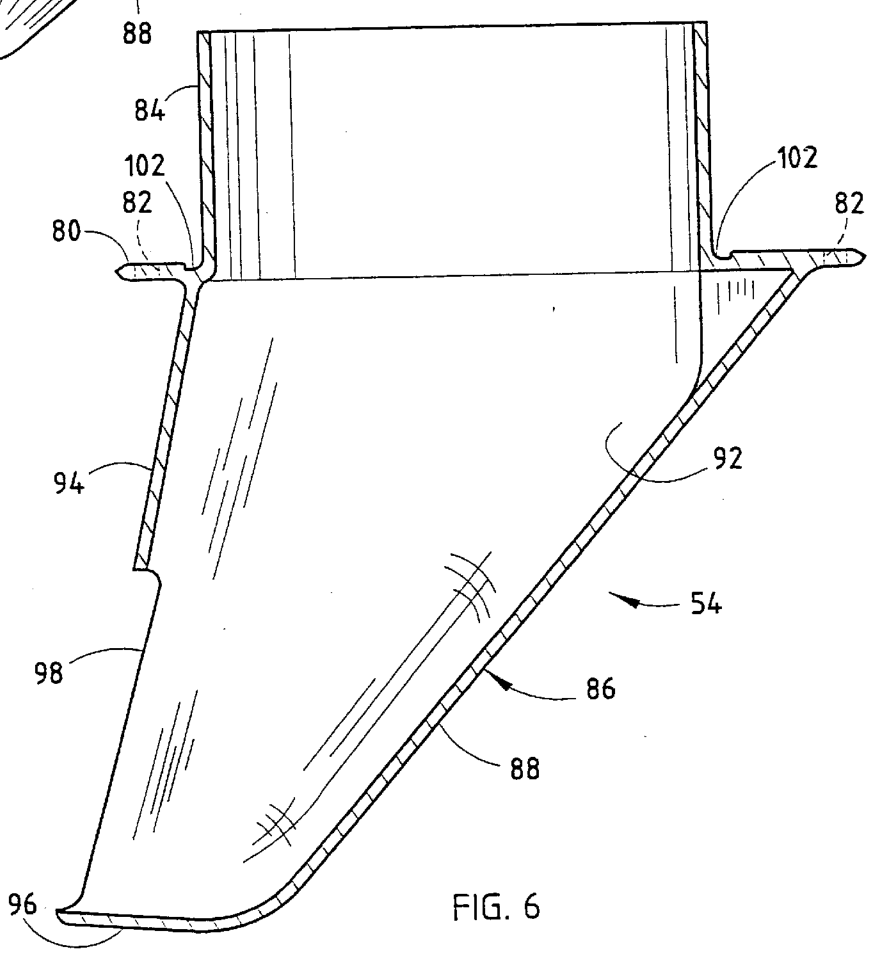
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FIG. 6

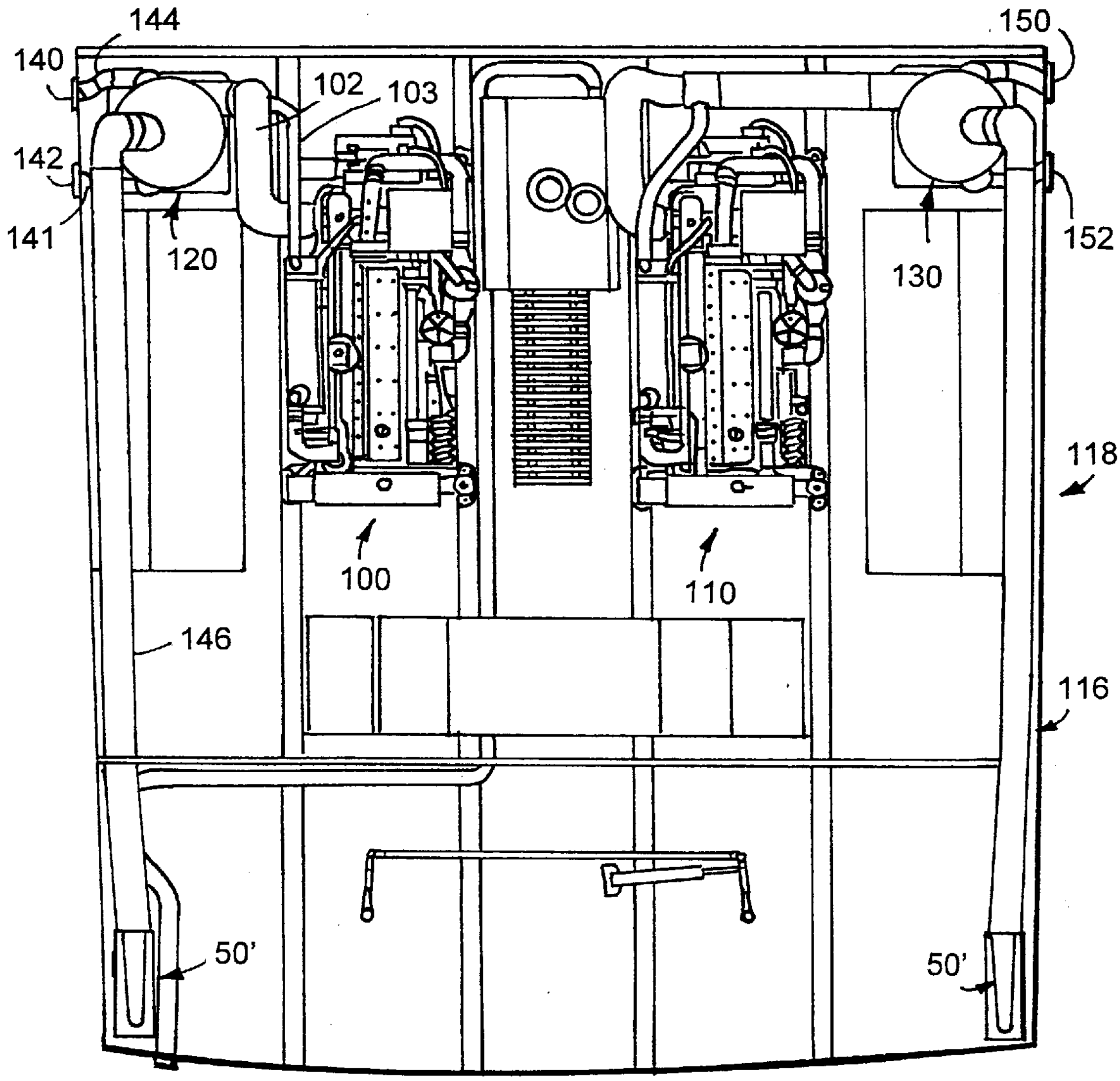


Fig. 7

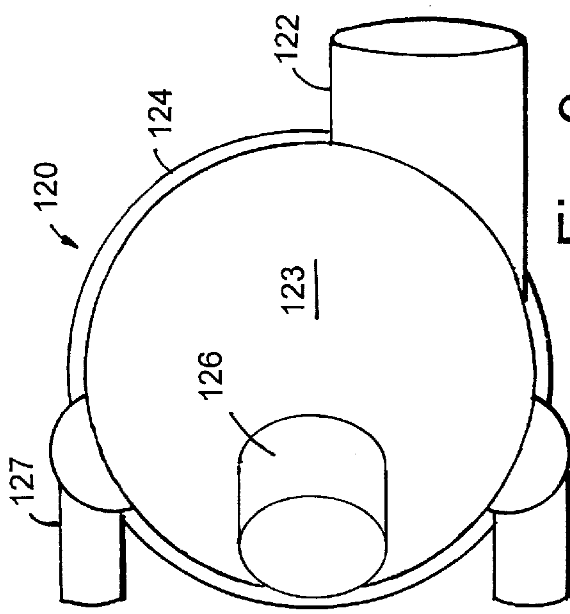


Fig. 9

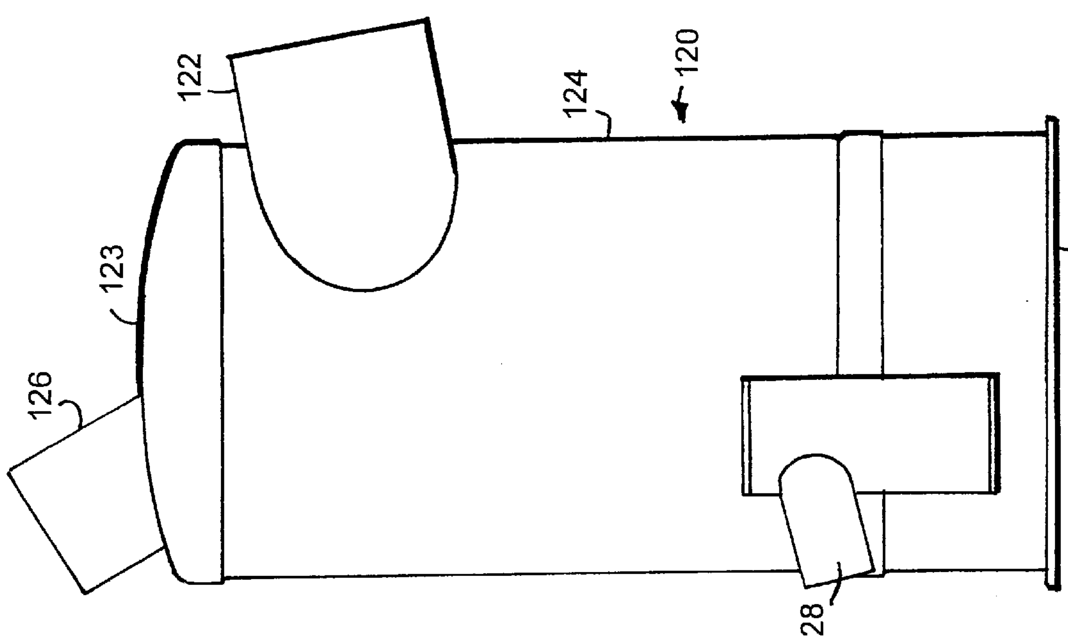


Fig. 8

EXHAUST SYSTEM FOR MARINE VESSELS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. § 119(*e*) on U.S. Provisional Application No. 60/040,039 entitled EXHAUST AND MUFFLER SYSTEM FOR MARINE VEHICLES, filed on Mar. 5, 1997, for Applicant Adam Rolinski, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates to an exhaust system for marine vessels such as yachts and smaller boats with inboard engines and particularly to a system for the underwater discharge of exhaust gases and the separation of exhaust gases and water prior to discharge from the system at running speeds.

Marine vessels such as yachts and boats incorporate gas or diesel engines for propulsion. Such engines produce foul smelling exhaust gases, soot and a significant level of engine noise. A challenge in the design of pleasure boats and yachts is to simnultaneously efficiently discharge such exhausts from the engines, minimize the passenger's contact with a such exhaust gases and reduce engine noise.

One solution to the engine noise problem is to provide a muffler which receives the exhaust gases and discharges the gas from the boat above the waterline. It is also known to discharge the exhaust gases below the waterline or a combination of above and below the waterline. Known mufflers include a dry system that uses baffles to muffle the sound and wet systems that mix water drawn in through a hull fitting with the exhaust gases. Typically, the water is mixed with the hot exhaust gases and then simultaneously discharged from the boat through a single common outlet. Below the waterline discharge systems provide a more effective means for muffling the engine noise than above the waterline systems except that an underwater system can result in back pressure for the engines and "burping" of the gases at idle or slow speeds.

SUMMARY OF THE PRESENT INVENTION

The system of the present invention overcomes the problems of prior art exhaust systems by utilizing a two pathway exhaust and water discharge through-hull system which is coupled to a muffler for separating exhaust gases and cooling water at operating speeds such that at low engine speeds exhaust gases and water are discharged through a first outlet(s) preferably above the waterline and, when the engine speed is increased, exhaust gases are discharged through a second gas outlet which communicates with a streamlined, low back-pressure underwater discharge skeg and only water is discharged through the first outlet. In a preferred embodiment of the invention, a discharge skeg is mounted to the bottom of the hull and positioned at each comer of the transom for a twin engined vessel. In a preferred embodiment also, each of the underwater discharge skegs includes a mounting flange and an upwardly extending collar which extends through the hull and is coupled to an adapter for sealably coupling the discharge skeg to the hull and to an exhaust outlet of a muffler. As a result, an exhaust system is provided which is efficient, quite and which discharges exhaust gases underwater and away from the vessel when underway at normal operating speeds.

These and other features, objects and advantages of the present invention will become apparent upon reading the following description thereof together with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a fragmentary top plan, schematic view of a twin engine vessel incorporating a muffler and exhaust system according to the invention;

FIG. **2** is a side elevational view of the port muffler shown in FIG. **1** for use according to the invention;

FIG. **3** is a top plan view of the muffler of FIG. **2**;

FIG. **4** is a perspective view of the exhaust discharge skeg assembly of the exhaust system of the invention;

FIG. **5** is a vertical cross-sectional view of the skeg adapter taken along lines V—V of FIG. **4**;

FIG. **6** is a vertical cross-sectional view of the exhaust skeg taken along lines VI—VI of FIG. **4**;

FIG. **7** is a fragmentary top plan schematic view of a vessel having a twin diesel engine exhaust system of the present invention;

FIG. **8** is a rear elevational view of the port muffler shown in FIG. **7**; and

FIG. **9** is a top plan view of the muffler shown in FIG. **8**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and to FIG. **1** in particular, there is shown a fragmentary plan schematic view of a twin gasoline engine vessel incorporating mufflers and an exhaust system according to the present invention. In this embodiment, starboard and port conventional gasoline internal combustion engines **12**, **14** are mounted inside the hull **16** of the vessel **18**. The structure of the starboard and port engines, mufflers, and exhaust system are identical and, therefore, only one system will be described in detail.

Each engine includes a pair of exhaust manifolds **20**, **22** provided thereon which convey the hot exhaust gases from the piston cylinders to the exhaust and muffler system. As in other conventional gas internal combustion engines, water is sprayed into the exhaust gas stream inside or adjacent to the exhaust manifold. The water is drawn into the engine through a conventional through-hull fitting (not shown) by a conventional water pump (not shown). A pair of gas conduits **24**, **26** extend from the manifolds **20**, **22** and terminate at a T-connector **28**. The gas and water mixtures from each manifold are commingled in the T-connector **28** and are conducted to the inlet port **30** (FIG. **2**) of muffler **32** through a conduit **29**. Muffler **32** is mounted to hull **16** to extend vertically in the vessel oriented as seen in FIGS. **1** and **2**. As seen in FIGS. **1–3**, the inlet port **30** extends tangentially onto the cylindrical housing **36** (FIG. **2**) of the muffler **32** at a location approximately one-third of the distance up from the bottom **34** of the muffler. Therefore, as the hot gas and water mixture enters the circular housing **36** of the muffler **32**, circular or cyclonic flow of this gas and water mixture is created along the inner wall of muffler **32**. When the velocity of such mixture increases at certain engine speeds, the exhaust gas and water mixture is separated into its constituent elements of waste water and exhaust gas.

As seen in FIGS. **1–3**, a first or water outlet **38** extends into muffler housing **36** below the inlet port **30** and near bottom **34**. Outlet **38** is, as best seen in FIG. **3**, angularly disposed on the opposite side of housing **36** from inlet **30** and extends tangentially from the sidewall **31** of muffler **32** in a direction opposite inlet **30**. A second or gas outlet **40**

extends into muffler **32** above the inlet port **30** about midway on the circular housing **36**. As best seen in FIGS. **2** and **3**, outlet **40** is angularly located between inlet **30** and first outlet **38** and extends not tangentially but instead orthogonally through wall **31** of muffler **32**. Cylindrical muffler **32** is preferably made of fiberglass and has a diameter of about 13 inches and a height of about 31 inches and is enclosed with a domed top **33**. The diameter of inlet **30** is about 15 inches, first outlet **38** is 3 inches and second outlet **40** is 4 inches. At low engine speeds such as idling below 1000 rpm, gas and water both exit first outlet **38**. At higher engine speeds as the exhaust velocity increases, the gas and water mixture enters the circular housing **36** through the tangentially oriented inlet port **30**, circular or cyclonic flow is created inside the circular housing **36** causing the waste water to drop in the housing for discharge through the water outlet **38** whereas the exhaust gases are separated from the water and pass through the gas outlet **40**. A conduit **42** extends from the first outlet **38** to a conventional brass through-hull fitting **44** for discharge into the water outside the hull. Preferably, the through-hull fitting **44** is positioned above the waterline of the vessel **18** at least when the vessel is not underway.

As seen in FIGS. **1** and **4–6**, an exhaust gas conduit **46** extends from the second or gas outlet **40** of muffler **32** rearwardly to an underwater gas discharge skeg assembly **50** for discharge from the vessel **18**. The skeg assembly **50** comprises a skeg adapter **52** positioned inside the boat hull **16** which mates with an underwater exhaust discharge skeg **54** mounted to the bottom of the hull **16** near each corner of the transom **15**, as seen in FIG. **1**. The skeg adapter **52** is integrally cast of a material suitable for the marine environment, such as bronze, and includes a base plate or mounting flange **56** having a plurality of fastener apertures **58** formed therein and a hollow, generally elliptical collar **60** extending upwardly therefrom. Preferably, the collar **60** comprises a pair of non-parallel side walls **62, 64**, a rounded leading edge **66**, and a rounded trailing edge **68**. The radius of the leading edge **66** is less than that of the trailing edge **68** so that the profile of the collar **60** is wider adjacent the trailing edge **68** than adjacent the leading edge **66**. Adapter **52** integrally includes an elbow conduit **72** serving as a transition section extending from generally elliptical collar **60** and terminating at a circular inlet end **74** adapted to receive the terminal end of the circular exhaust gas conduit **46**. End **74** includes an external circular sealing bead **71** to assist in sealably attaching exhaust hose or conduit **46** to adapter **52** by the use of conventional hose clamps. The elbow connector **72**, thus, provides a smooth transition from the preferably circular cross section of the exhaust gas conduit **46** to the generally elliptical cross section of the gas discharge opening **65** of skeg adapter **52**. The bottom surface of base or mounting flange **56** includes an upwardly extending continuous recess **100** (FIG. **5**) for receiving conventional marine sealing material for sealing the adapter to the inside of hull **16** when through-hull fasteners couple adapter **52** and skeg **54**.

The skeg **54** comprises an integrally cast member which is generally streamlined to minimize underwater drag. Exhaust skeg **54** is trapezoidal when viewed from the side (FIG. **6**) and thin with curved sidewalls, a narrow rounded leading edge **86** and an exhaust outlet **98** along the lower trailing edge. Exhaust skeg **54** includes a base plate or mounting flange **80** with a plurality of fastener apertures **82** formed therein to align with the fastener apertures **58** of the skeg adapter base plate **56**. A hollow elliptical collar **84** extends upwardly from plate **80**. The shape of the collar **84** is selected to fit within the interior surface collar **60** of skeg

adapter **52**. Collar **84** has a height which extends through the thickness of hull **16** which includes an aperture sized to closely receive upstanding collar **84**. The hollow body **86** of skeg **54** extends downwardly from the base plate **80** and has a rearwardly and downwardly tapered leading edge **88**, a pair of opposed, non-parallel side walls **90, 92**, a trailing edge **94** and a bottom edge **96**. Preferably, the cross section of the skeg body **86** comprises a hydrodynamically efficient foil shape which is symmetrical about its centerline. The leading edge **88** is rounded and has a relatively small radius of curvature whereas the trailing edge **94** is substantially planar and dimensioned so that the side walls **90, 92** diverge away from one another as the distance from the leading edge **88** increases. The sides **90, 92** converge slightly at the trailing rounded edge **94** of the skeg **54**. The skeg body **86** is hollow and has an exhaust outlet aperture **98** formed through at least a substantial portion of the trailing edge **94**. The mounting base or flange **80** of skeg **54** includes a recess **102** extending continuously around the upper surface of flange **80** adjacent the intersection of the plate **82** and collar **84**. Recess **102** receives a conventional marine sealant.

The skeg adapter **52** and skeg **54** are adapted to be assembled to one another through the hull on opposite sides of the bottom to create the skeg assembly **50**. The elliptical collar **84** of the exhaust skeg **54** is telescopically received inside the hollow interior of the collar **60** of the skeg adapter **52**. In the assembled condition, the two base plates **56, 80** are aligned and abut opposite sides of the hull. Conventional threaded fasteners extend through the apertures **58, 82** of the two plates **56, 80**, respectively, for securing these two members to one another and the resultant skeg assembly **50** to the hull **16**. A bead of conventional marine sealant is provided in the sealant grooves **100, 102**, respectively, prior to assembly of the two members to the hull. Once assembled, the sealant prevents water from leaking into the hull **16**.

The exhaust system according to the invention provides significant improvements over prior exhaust systems. In operation, exhaust gases generated by operation of the engines **12, 14** are mixed with water in or adjacent to the manifolds **20, 22**. The gas and water mixture enters the mufflers **32**. Below a predetermined engine speed, typically while the vessel is at a dock and the engines are idling, insufficient cyclonic flow is created inside the muffler to separate the gas and water mixture. Additionally, not enough water volume flows to seal or fill the water outlet **38**, allowing a path for gases to flow out of outlet **38**. Therefore, all of the gas and water will be discharged from the boat through the water outlet **38**, waste water conduit **42**, and ultimately, the through-hull fitting **44**. As the engine speed increases, sufficient velocity of fluid flow generated by the expulsion of the exhaust gases and injection of water creates a cyclonic flow inside the cylindrical muffler housing **36** to separate the exhaust gases from the waste water. Sufficient water is pumped to muffler to occupy all space in water outlet **38** such that the gases are rerouted to outlet **40** of muffler **32**. The pressure difference between inlet **30** and outlet **38** must be greater than between inlet **30** and outlet **40** for this to occur. Preferably, the desired, transitional engine speed is approximately 1,000 rpm. As the engine speed exceeds this level, the water separates from the gas and is discharged through the through-hull fitting **44**. The gases, on the other hand, are discharged from the muffler **32** through the gas outlet **40** and are conducted to the skeg assembly **50** via the exhaust gas conduit **46** and conduit connector **74**. The exhaust gases flow through the collars **60, 84** into the hollow skeg body and are discharged rearwardly from the boat

through the outlet aperture **98** provided in the trailing edge **94**. The skeg assemblies **50** are mounted on the boat hull **16** so that the skegs **54** are positioned beneath the waterline when the vessel is at rest and at planing speeds. Therefore, above the threshold engine speed where gas and water separation occurs and the back pressure of outlet **40** is less than at outlet **38**, most of the exhaust gases are discharged from the boat **18** through the outlet aperture **98** of the skeg member **54**, below the waterline.

Separation of the gas and water above certain engine speeds in combination with the position and contour of the skeg assembly **50**, results in several significant advantages. First, the engine noise level is dramatically reduced. Secondly, the odorous exhaust gasses are discharged underwater in the wake of the vessel. With this structure, it has been found that little or no exhaust gases roll back up into the passenger cockpit area, known as the station wagon effect, under normal operating conditions. The aerodynamic contour of the skeg **54** effectively channels and discharges the exhaust gases into the water where the noise is absorbed and effectively conducted away from the moving vessel. The first embodiment of the exhaust and muffler system described above in reference to FIGS. **1–6** is ideally suited for a gasoline burning internal combustion engines. This system can be employed for use for diesel engines as shown in FIGS. **7–9** now described.

Referring to FIG. **7**, there is shown a vessel **118**, such as a **40** foot express yacht manufactured by S2 Yachts Inc. of Holland, Michigan, which includes a hull **116** which, as shown schematically in FIG. **7**, includes port and starboard engines **100**, **110**, respectively. Engines **100**, **110** are diesel engines which are in-line six-cylinder turbo-charged engines with an exhaust system according to the present invention which is substantially similar as that described in the embodiment shown in FIGS. **1–6** with the exception that the exhaust passageways and muffler are somewhat larger for the increased volume of exhaust gases and water discharged by the larger engines. Also, each of the mufflers **120**, **130** include dual outlets as described below. The exhaust systems and engine installations are mirror images of one another, such that only the port installation is described in detail in connection with FIGS. **7–9**.

The port engine **100** includes an exhaust riser **102** extending from the engine to which there is injected through hose **103** a substantial amount of cooling water for the hot exhaust gases which enter muffler **120** through an exhaust inlet **122** located near the top of the muffler **120**. Muffler **120** includes a cylindrical sidewall **124**, a bottom **121** and a domed top **123** which includes an exhaust gas outlet **126**. Extending outwardly from the opposite sides of the muffler **120** are water outlets **127** and **128** which are coupled to through-hull fittings **140**, **142** above the waterline of the hull by means of hoses **141**, **144** connected by conventional hose clamps. An exhaust hose **146** is coupled to the outlet **126** of muffler **120** and extends aft in the vessel to an exhaust skeg assembly **50'** which is substantially identical to the skeg **50** shown in FIGS. **4–6** with the exception that it is somewhat larger such that the discharge apertures **65** and **98** therein are somewhat larger to accommodate the greater flow of gases from the larger diesel engines.

As can be appreciated, mufflers **120** and **130** may be somewhat larger in overall size and scaled up in dimension than the muffler **32** in the gasoline version of the exhaust system of the present invention. As in the first embodiment, the inlet **122** is positioned below the gas outlet **126** while the water outlets **127** and **128** are located near the bottom **121** of the muffler **120**. The starboard engine **110** includes similar

connections to its muffler **130** which, in turn, is coupled to through-hull fittings **150**, **152** for the discharge of water and gas and water when the engines are idling therefrom as well as to an exhaust gas skeg assembly **50'** on the starboard corner of the transom area of the vessel.

In the embodiment shown in FIGS. **7–9**, at low engine speeds, such as at idling below or near 1000 rpm, exhaust gas and water are discharged through the above water dual through-hull fittings **140**, **142**, **150**, **152**. As engine speed is increased above the idle speed when the vessel is underway, the heavier water tends to separate and drop by centrifugal action in the mufflers **120**, **130**, and the increased gas velocity and venturi action of the movement of exhaust skegs **54** through the water assists in drawing the gases through underwater exhaust opening **98** (FIG. **6**). In the diesel version shown in FIGS. **7–9**, exhaust opening **98** may be larger (i.e. extend a greater distance along trailing edge **94** of skeg **54**). Thus, at running speeds, gas escapes through the gas discharge port **126** of the muffler and be discharged through the underwater exhaust skeg assemblies **50'** while water collected at the bottom of the muffler drains through the through-hull fittings from the discharge outlets **127**, **128** of muffler **120** and similar outlets on muffler **130**. Thus, the exhaust system shown in FIGS. **7–9** functions to efficiently discharge cooling water as well as exhaust gases from the vessel discharging the exhaust gases into and below the slip behind the vessel when underway through the use of the exhaust skegs **50'** of a construction substantially the same as that shown in FIGS. **4–6**.

For different vessels and/or different engines, the size of the mufflers, number of seawater discharge openings and size of the skeg assemblies can be appropriately scaled up or down. Such reasonable variations and modifications are possible within the spirit of the foregoing specification and drawings without departing from the scope of the invention.

It will become apparent to those skilled in the art that various modifications to the preferred embodiments of the invention as described herein can be made without departing from the spirit or scope of the invention as defined by the appended claims.

The invention claimed is:

1. An exhaust system for an engine of a marine vessel comprising:

a muffler for separating the exhaust gas and water components from a marine engine exhaust above a predetermined engine speed, said muffler having an exhaust gas inlet adapted to be coupled to an engine, an exhaust gas outlet, and at least one water outlet;

conduit means coupling said water outlet to a first through-hull fitting adapted to be positioned above the waterline of a vessel for exhausting substantially all of the engine exhaust gas and engine cooling water below said predetermined speed;

an exhaust skeg assembly including an underwater exhaust skeg; and

exhaust conduit means for coupling said skeg assembly to said gas outlet of said muffler for discharging substantially only the engine exhaust gas below the vessel waterline when the engine is above said predetermined speed.

2. The exhaust system as defined in claim **1** wherein the skeg assembly comprises a hollow generally trapezoidal shaped exhaust skeg having curvilinear sides, a narrowly rounded leading edge and an exhaust port formed through a trailing edge.

3. The exhaust system as defined in claim **1** wherein said predetermined engine speed is about 1000 RPM.

4. An exhaust system for a marine vessel comprising:

a muffler for separating the exhaust gas and water components from a marine engine exhaust, said muffler having an exhaust gas inlet adapted to be coupled to an engine, an exhaust gas outlet, and at least one water outlet;

conduit means coupling said water outlet to a first through-hull fitting adapted to be positioned above the waterline of a vessel;

an exhaust skeg assembly including an underwater exhaust skeg, wherein said skeg assembly comprises a hollow generally trapezoidal shaped exhaust skeg having curvilinear sides, a narrowly rounded leading edge and an exhaust port formed through a trailing edge, and wherein said exhaust skeg further includes an upwardly extending collar communicating with the hollow interior of said exhaust skeg and a peripheral sealing recess extending adjacent said upwardly extending collar for receiving a sealing material and a peripheral flange for sealably mounting said skeg to the bottom of the vessel with said collar extending upwardly through an aperture formed in the hull; and

exhaust conduit means for coupling said skeg assembly to said gas outlet of said muffler for discharging gas below the vessel waterline.

5. The exhaust system as defined in claim **4** wherein said skeg assembly further includes a skeg adapter having a collar mateably receiving said collar of said exhaust skeg and an elbow for coupling to said exhaust conduit means extending between said skeg adapter and said gas outlet of said muffler.

6. The exhaust system as defined in claim **5** wherein said skeg adapter includes a mounting flange communicating with said collar and a sealing recess extending around said mounting flange adjacent said collar for receiving a sealing material for sealably attaching said skeg adapter to the inside of a hull in aligned mating relationship to said exhaust skeg.

7. The exhaust system as defined in claim **6** wherein said mounting flange of said exhaust skeg and said mounting flange of said skeg adapter include aligned apertures therein for receiving through-hull fasteners for attaching said skeg adapter and exhaust skeg to opposite sides of the hull of a vessel.

8. An exhaust system for a marine vessel comprising:

a muffler for separating the exhaust gas and water components from a marine engine exhaust, said muffler having an exhaust gas inlet adapted to be coupled to an engine, an exhaust gas outlet, and at least one water outlet, wherein said muffler comprises a generally cylindrical, vertically extending housing with a cylindrical wall and wherein said gas inlet extends tangentially through said cylindrical wall;

conduit means coupling said water outlet to a first through-hull fitting adapted to be positioned above the waterline of a vessel;

an exhaust skeg assembly including an underwater exhaust skeg; and

exhaust conduit means for coupling said skeg assembly to said gas outlet of said muffler for discharging gas below the vessel waterline.

9. The exhaust system as defined in claim **8** wherein said gas outlet is positioned vertically above said gas inlet and extends outwardly from said wall of said muffler.

10. The exhaust system as defined in claim **9** wherein said at least one water outlet extends from said cylindrical wall and is positioned below said gas inlet.

11. An exhaust skeg assembly for a marine vessel comprising:

a generally hollow exhaust skeg having curvilinear sides, a narrow rounded leading edge and an exhaust port formed in the trailing edge thereof, wherein said leading edge tapers toward said trailing edge from top to bottom to define a trapezoidal profile skeg; and

a skeg adapter mateably coupled to said exhaust skeg and including means at an end remote from said exhaust skeg for coupling to an exhaust conduit.

12. The Exhaust skeg assembly as defined in claim **11** wherein said exhaust skeg includes an upwardly extending collar.

13. An exhaust skeg assembly for a marine vessel comprising:

a generally hollow trapezoidal shaped exhaust skeg having curvilinear sides, a narrow rounded leading edge and an exhaust port formed in the trailing edge thereof, wherein said exhaust skeg includes an upwardly extending collar, and wherein said exhaust skeg includes a peripheral mounting flange including a sealing groove extending adjacent said upwardly extending collar for mounting said skeg to the bottom of a vessel with said collar extending upwardly through an aperture formed in the vessel; and

a skeg adapter mateably coupled to said exhaust skeg and including means at an end remote from said exhaust skeg for coupling to an exhaust conduit.

14. The exhaust skeg assembly as defined in claim **13** wherein said skeg adapter includes a mounting flange communicating with said collar and a sealing recess extending around said mounting flange adjacent said collar for receiving a sealing material for attaching said skeg adapter to the inside of a hull in aligned mating relationship to said exhaust skeg.

15. An exhaust system for an engine of a marine vessel comprising:

a muffler for separating the exhaust gas and water components from a marine engine exhaust above a predetermined engine speed, said muffler having an exhaust gas inlet adapted to be coupled to an engine, an exhaust gas outlet spaced in opposed relationship to said inlet, and at least one water outlet for exhausting substantially all of the engine exhaust gas and engine cooling water below said predetermined engine speed;

a substantially thin streamlined underwater exhaust skeg for mounting to the bottom of a vessel; and

means for coupling said exhaust skeg to said gas outlet of said muffler for discharging substantially only the engine exhaust gas below the vessel waterline when the engine is above said predetermined speed.

16. The exhaust system as defined in claim **15** wherein said exhaust skeg comprises a hollow generally trapezoidal shaped skeg having curvilinear sides, a narrowly rounded rearwardly tapered leading edge, and an exhaust port formed through a trailing edge.

17. The exhaust system as defined in claim **16** wherein said exhaust skeg includes an upwardly extending generally elliptical collar communicating with the hollow interior of said exhaust skeg.

18. An exhaust system for a marine vessel comprising:

a muffler for separating the exhaust gas and water components from a marine engine exhaust, said muffler having an exhaust gas inlet adapted to be coupled to an engine, an exhaust gas outlet spaced in opposed relationship to said inlet, and at least one water outlet;

a substantially thin streamlined underwater exhaust skeg for mounting to the bottom of a vessel, wherein said exhaust skeg comprises a hollow generally trapezoidal shaped skeg having curvilinear sides, a narrowly rounded rearwardly tapered leading e, an exhaust port formed through a trailing edge, and an upwardly extending generally elliptical collar communicating with the hollow interior of said exhaust skeg, and wherein said exhaust skeg includes a peripheral sealing recess extending adjacent said upwardly extending collar for receiving a sealing material and a peripheral flange for sealably mounting said skeg to the bottom of the vessel with said collar extending upwardly through an aperture formed in the hull; and

means for coupling said exhaust skeg to said gas outlet of said muffler for discharging gas below the vessel waterline.

19. The exhaust system as defined in claim **18** wherein said means for coupling said exhaust skeg to said gas outlet includes a skeg adapter having a collar shaped to mate with said collar of said exhaust skeg and a transition section terminating in a generally circular end for coupling to a gas conduit.

20. The exhaust system as defined in claim **19** wherein said skeg adapter includes a mounting flange communicating with said collar and a sealing recess extending around said mounting flange adjacent said collar for receiving a sealing material for attaching said skeg adapter to the inside of a hull in aligned mating relationship to said exhaust skeg.

21. The exhaust system as defined in claim **20** wherein said mounting flange of said exhaust skeg and said mounting flange of said skeg adapter include aligned apertures therein for receiving through-hull fasteners for attaching said skeg adapter and exhaust skeg to opposite sides of the hull of a vessel.

22. The exhaust system as defined in claim **21** wherein said muffler comprises a generally cylindrical, vertically extending housing with a cylindrical wall and wherein said gas inlet extends tangentially through said cylindrical wall.

23. The exhaust system as defined in claim **22** wherein said gas outlet is positioned vertically above said gas inlet and extends outwardly from said wall of said muffler spaced approximately 180° from said gas inlet.

24. The exhaust system as defined in claim **23** wherein said at least one water outlet extends from said cylindrical wall and is positioned below said gas inlet.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,980,343
DATED : November 9, 1999
INVENTOR : Adam Rolinski

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Abstract, line 11;
"comer" should be --corner--.

Abstract, line 18;
"quite" should be --quiet--.

Column 1, line 57;
"comer" should be --corner--.

Column 1, line 63;
"quite" should be --quiet--.

Column 5, line 24;
delete "a".

Column 6, line 19;
"be" should be --is--.

Column 8, line 11;
"Exhaust" should be --exhaust--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,980,343 Page 2 of 2
DATED : November 9, 1999
INVENTOR : Adam Rolinski

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9, line 5;
"e," should be --edge,--.

Signed and Sealed this

Seventh Day of November, 2000

Attest:

Q. TODD DICKINSON

Attesting Officer *Director of Patents and Trademarks*

Exhibit 8

United States Patent [19] [11] **3,835,625**
Williams [45] **Sept. 17, 1974**

[54] **POLLUTION-REDUCING FLOATING EXHAUST**

[76] Inventor: **Cecil E. Williams,** 334 Awini Pl., Honolulu, Hawaii 96825

[22] Filed: **July 20, 1973**

[21] Appl. No.: **381,260**

[52] **U.S. Cl.**................ **55/259,** 55/385, 55/DIG. 30, 98/58, 110/119, 110/184, 114/187
[51] **Int. Cl.**.. **B01d 47/06**
[58] **Field of Search** 55/220, 259, 385, 310, 55/DIG. 30; 110/119, 184; 114/187; 98/58–60

[56] **References Cited**

UNITED STATES PATENTS

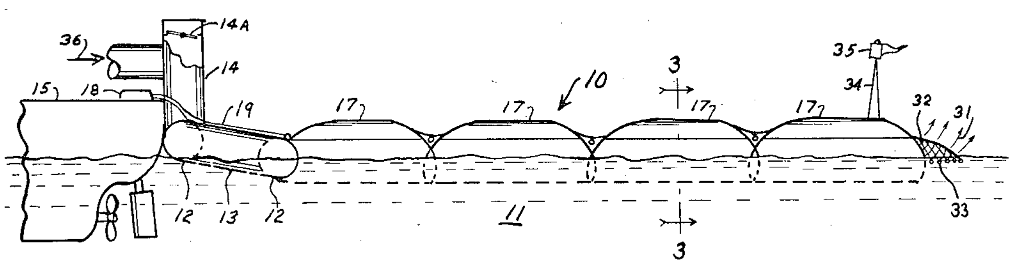
2,885,988	5/1959	Myers	114/235 R
3,242,893	3/1966	Mortarino	114/187
3,489,072	1/1970	Secor	110/184
3,701,235	10/1972	Issacson	55/220
3,740,930	6/1973	Cullom	98/60

Primary Examiner—Bernard Nozick
Attorney, Agent, or Firm—Brenner & Wray

[57] **ABSTRACT**

An articulated floating exhaust stack trails behind a ship to cool exhaust and to remove particulated matter. Exhaust flows through a universal joint to multiple articulated sections and contacts water along the bases of the trailing sections. Water sprays within the sections cool and wash the gases. Baffles slow and lengthen flow. Waves clean channels, baffles, and filters.

14 Claims, 7 Drawing Figures



PATENTED SEP 17 1974 3,835,625

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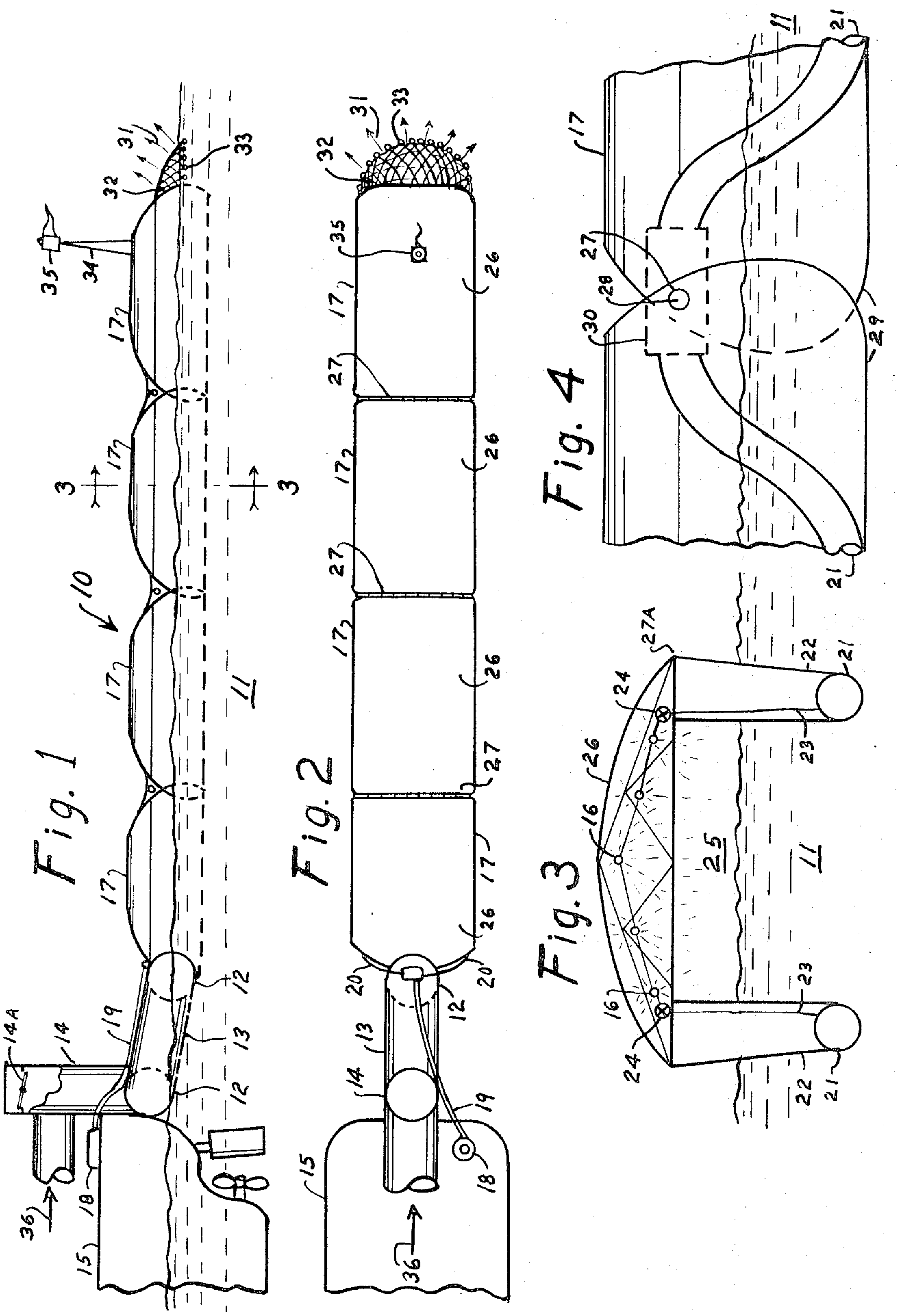

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3,835,625

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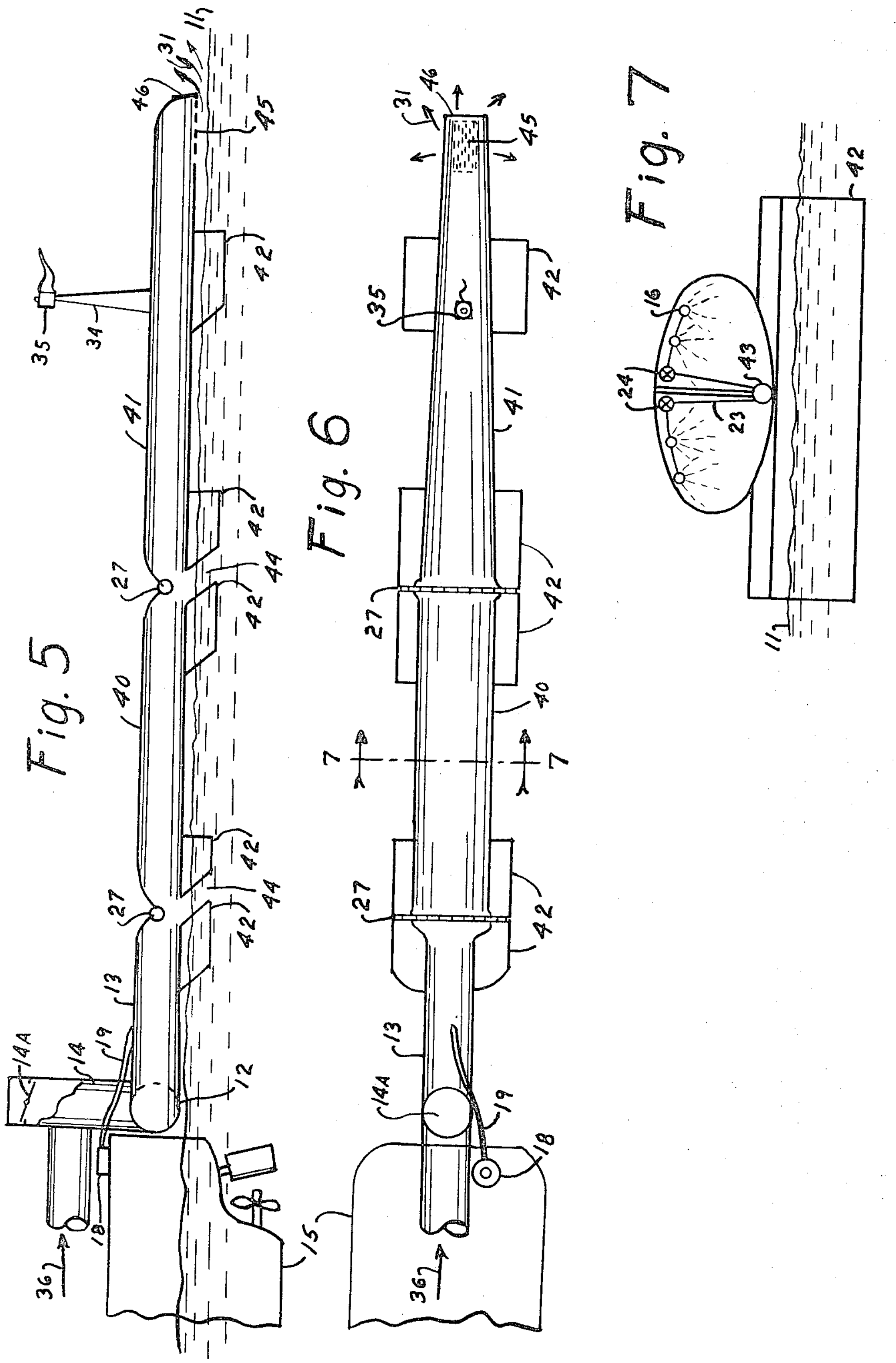


POLLUTION-REDUCING FLOATING EXHAUST

BACKGROUND OF THE INVENTION

This invention relates generally to the cooling, cleaning, filtering, and dispersal of waste gases produced during the operation of incinerators, refuse destructors, steam generators, and chemical processes. Most large incinerators and steam generators now utilize various forms of water spray chambers and wet scrubbers to remove particulate matter from their waste gases and to thus reduce atmospheric pollution. These chambers and scrubbers are bulky, consume large volumes of water, and usually require filtration of the process water to remove collected particles. Their arrangement and principles of operation are well understood and described in the literature. Corey, Richard C., editor Principles and Practices of Incineration; Wiley Interscience, New York, 1969, LC75-78479, gives the mathematical relationships, physical principles, and mechanical arrangements for several forms of spray washers and scrubbers.

Incinerators, and steam generators, used on ships require effective cleaning of waste gases produced during operation. Space limitations and other design considerations restrict the application and effectiveness of waste-gas cleaning equipment on shipboard.

SUMMARY OF THE INVENTION

The limitations of the prior art are partially overcome by a floating exhaust system supported by the water surface adjacent to the ship as described herein. The design includes flexible joints in the waste gas channels to permit relative motion of the ship and the floating exhaust system. The large amount of cool water available and the self-cleaning features possible are employed. Particulate matter settles directly into the supporting water, or is captured by spray droplets. Draft is supplied by the outlet pressure of the induced-draft fans such as are normally used with incinerators and steam generators.

In accordance with the present invention there is provided apparatus for cooling, cleaning, and disposing of particulate matter and soluble substances contained in waste gases. Such gases arise from the operation of steam boilers and incinerators on ships. The present invention is especially applicable for use with the rotary incinerator invention which is disclosed in a copending application Ser. No. 381,262 filed 7/20/73. This processing is carried out in an elongated structure buoyantly supported on the water and suitably connected to receive waste gases from a ship or other source.

In one example, the floating exhaust system consists of an array of sections each comprised of two parallel pontoons, which form the two sides of the gas channel and a roof section which connects the top of the two pontoons and forms the top of the gas channel. These sections are connected in sequence to form a substantially rectangular gas channel whose lower boundary is the surface of the supporting water.

Spray nozzles mounted inside this gas channel cool the structure and the waste gases, while washing out suspended particles and dissolving soluble components. Spray water, heat, and removed material returns to the supporting body of water for dispersion by natural processes. Washed and cooled gases return to the atmosphere through an outlet at the end of the waste gas channel.

Spray water is supplied through hoses by pumps located on the ship. Sections of the floating gas channel are articulated to follow the surface of the water. Various types of diverters, baffles, and screens are placed inside the gas channel in some embodiments to increase the effectiveness of the particle removal or cooling action. In a preferred embodiment the cross section of the channel is reduced as the waste gases contract in cooling. In some examples screened vents are provided along the duct to disperse portions of the waste gas.

Another embodiment of this invention is a buoyant tubular structure arranged to trail behind the ship while cleaning and exhausting waste gases. A layer of cooling water is normally present along the bottom side of the tube interior. This water sloshes against the sides of the enclosing tube as wave motion is transmitted to the tube. Articulate joints are provided to reduce stresses caused by large wave motion. A large shrouded opening to the water below is provided at each articulated joint to serve as an outlet for excess water and collected particles. The buoyant structure supporting the gas tube is arranged to support the gas tube a small distance above the water surface under normal conditions. Cooled and washed gases exit in a downward direction through a large screened opening in the lower surface of the end section of the tube. The screen over the opening is periodically washed by wave action which periodically floods the outlet. A safety pressure-relief outlet is also provided to handle unusual hydraulic surges without damage to the tube.

It is an object of the present invention to provide a method of and apparatus for cooling, cleaning, removing particulate and soluble matter from waste gases.

A further object of the present invention is to provide apparatus to cool and clean the waste gases originating on ships or floating structures by equipment flexibly connected to the ships utilizing separate means of flotation.

Another object of the present invention is to reduce the total height of ships by replacing tall exhaust stacks with horizontal floating stacks which are towed behind the ships.

A still further object of this present invention is to reduce the visibility and atmospheric pollution of incinerator ships operated in coastal waters to dispose of refuse collected from nearby cities.

The invention has as another object the provision of a separate, floating system for cooling and cleansing waste gases produced on a ship or similar floating structure.

Another object of the invention is the provision of a cooling and cleaning system for waste gases using the surface of the supporting body of water as an essential boundary and agent for removal of heat and particulate matter from waste gases.

A further object of the invention is the provision of an exhaust system which discharges waste gases downward against the water surface and in close proximity thereto.

Another object of the invention is the provision of an exhaust system which utilizes wave motion to clean filters, increase turbulence, and generally enhance the effectiveness of cleansing and cooling.

The invention has as another object the provision of an exhaust system to generate a substantial portion of

the water turbulence and spray dispersion utilized for cooling and cleansing.

A further object of the invention is the provision of underwater hydrofoils to support a floating exhaust system during high speed operation.

Another object of the invention is the provision of a ship exhaust system which greatly reduces the amount of particulate fallout upon the ship.

These and other objects and features of the invention are apparent in the disclosure which includes the drawings and the specification with the foregoing and ongoing description and with the claims, which are a part of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevation schematic view of a floating exhaust system connected to the stern of a ship and supported upon the surface of the water.

FIG. **2** is a schematic top plan view of a floating exhaust system trailing behind the stern of a ship.

FIG. **3** is a cross-section schematic view through one of the segments of the floating exhaust system, transverse to an elongated direction.

FIG. **4** shows additional details of a flexible joint seal, and the water pipe connections between segments of the floating exhaust system.

FIG. **5** is an elevation schematic view of a floating exhaust system with tubular channels.

FIG. **6** is a top plan schematic view of a floating exhaust system with tubular channel attached to a ship.

FIG. **7** is a partially sectioned detail view of a tubular channel floating exhaust system.

DETAILED DESCRIPTION OF THE DRAWINGS

In the drawings like elements are designated by the same reference characters. FIGS. **1, 2, 3,** and **4** illustrate a floating exhaust system **10,** which is buoyantly supported upon the surface of a body of water **11,** and which is connected through two flexible joints **12** and an inclined tube **13** to a fixed short vertical tube **14** on the stern **15** of a ship which carries the source of the hot waste gases **36** to be cooled and cleansed. This source may be a rotary incinerator, as disclosed in a co-pending application, or the normal combustion equipment supplying energy to operate the ship. This vertical tube **14** is normally closed at the top by a valve **14A.** The flexible joints **12** and tube **13** permit relative motions between the ship and the exhaust system **10** such as characteristically are produced by wind and wave forces acting upon the ship and system. The joints **12** each preferably are designed to flex ±90° in yaw, ±30° in roll, and ± 15° in pitch. The length of the tube **13** is sufficient to permit the exhaust system **10** to be brought alongside the ship for repairs, inspection, or emergency maneuvers.

Internal spray nozzles **16** located in the joints **12,** tube **13,** vertical tube **14,** and all floating segments **17** cool the waste gases and wash particulate matter from them. Spray nozzles **16** are also positioned to maintain the entire surrounding structure at a safe operating temperature. An engine-driven pump **18** located on the stern **15** of the ship lifts water from the supporting body of water and supplies it to the spray nozzles **16** through a pipeline **19.** Portions of said pipeline **19** are made flexible to accommodate relative motion between the stern **15** and the floating exhaust system **10.** Pipeline **19** divides into two parts **20** when it reaches the first segment **17,** and each of these parts **20** connects to a bottom pipe **21** located at the lower edge of each pontoon **22** of each segment **17.** As shown in FIG. **3** distribution tubes **23** located in each segment **17** supply groups of spray nozzles **16** through control valves **24,** which are adjusted to give the required intensity of spray inside the gas channel **25.**

Each segment **17** is fitted with a roof structure **26,** which supports the spray nozzles **16,** and which is attached to the two pontoons **22** by a gas-tight joint **27A.** This roof structure **26** also maintains the pontoons **22** upright and parallel. The roof **26** is shaped to shed water splashed upon it by waves and is constructed to allow some torsional deflection without damage. Joints **27** between segments **17** may be of the construction commonly referred to as piano-type which are secured by a hinge pin **28.**

Overlapping plate skirts **29** may be used to reduce gas leakage at the joints **27** as illustrated in FIG. **4.** The bottom pipes **21** are bent up to the level of the hinge pin **28** and flexibly are connected by a hose **30** to the pipe **21** of a following segment **17.**

Waste gases **36** enter the substantially rectangular gas channel **25** and are cooled and cleansed by the water from the spray nozzles **16** and by direct contact with the water surface. Particulate matter in the waste gases **36** settles into the supporting body of water. The gas channel **25** is designed to be wide and low to improve stability, to reduce the required settling distance for particulate matter, and to increase the cooling area of water surface inside. The actual cross-sectional area of the gas channel **25,** volume of spray water supplied, segment **17** length, and the number of segments **17** required for a given application are decided after a careful study of the composition and temperature of the incoming waste gases **36,** the amount of cooling and particulate removal required, the weather conditions in the area of operation, the properties of the available materials, and the economics of a given installation.

Cooled and cleansed gases **31** exit to the atmosphere through a reinforced mesh and fabric filter **32** attached to the end of the last segment **17** as shown in FIG. **1.** The lower edge of this filter **32** is attached to a line of floats **33** trailing on the surface of the water **11.** Wave action keeps this filter **32** wet and washes away collected particles. Since the discharged gases **31** are cool and low, there is increased time for any remaining particles to settle into the water surface **11** after leaving the exhaust system **10.** The situation is much more favorable for reducing pollution than when conventional stacks release hot waste gases containing particulate matter which is borne aloft by the buoyant gases.

The outer end segment **17** of the floating exhaust system **10** is equipped with a vertical mast **34** which carries a warning and identification package **35.** This package **35** contains a radar reflector, navigation lights, distinctive pennant, and other equipment as required by international law.

Another embodiment of a floating exhaust system **10** is shown in FIGS. **5, 6,** and **7.** Waste gases **36** originating on a ship are conducted through a tube **13** into an articulated series of cooling and washing chambers **40, 41,** which are of generally elliptical cross section as shown in FIG. **7.** These chambers **40, 41** are supported a short distance above the water surface by closed pontoons or hydrofoils of appropriate size and shape. Inter-

nal spray nozzles **16** located in the joint **12**, tube **13**, vertical tube **14**, and floating chambers **40, 41** cool the waste gases **36** and wash particulate matter from them. These spray nozzles **16** are supplied with water through pipeline **19** and valves **24** as described previously. Pipeline **19** connects to a distribution pipe **43** running longitudinally through chambers **40** and **41**.

Water from the nozzles **16** and trapped particulate matter returns to the supporting body of water through open ports **44** located between the pontoons **42** and below the hinge joints **27**. Waste gas **36** leakage to the atmosphere is prevented by overlapping plate skirts as illustrated previously in FIG. **4**. Wave motion causes sufficient sloshing of water through the chambers **40, 41** to remove all deposits of particles. Chambers **40, 41** may include interior frame structure to increase their strength. Aluminum or other suitable low-density material may be used as desired in fabrication. The outer end of chamber **41** is equipped with a short mast **34** and a navigation package **35** as previously described.

Cooled and cleansed gases **31** exit to the atmosphere through a series of filtered openings **45** located on the underside of chamber **41** at the outermost end. A spring-loaded safety valve **46** is also located in the outermost end of chamber **41** to relieve any overpressure caused by hydraulic transients. Wave action periodically washes and flushes particulate matter from the filtered openings **45**. A tapered construction is suggested for chamber **41** to reduce cost, weight, and inertia. Various baffles and obstructions may be placed in the chambers **40, 41** to direct the flow of gas and water, to increase turbulence and mixing, and generally to enhance the performance of particular designs. External water sprays may be added to maintain the outer surfaces at safe operating temperatures.

While mechanically pumped spray water is utilized in the examples illustrated this is not an essential feature of these exhaust systems when used with ships of moderate velocity. Very low heads are required to move water onto all surfaces of the exhaust system. These water heads may be developed by suitably designed scoops or ram tubes facing the direction of ship travel. A further refinement consists of the addition of underwater hydrofoils to lift the exhaust system and reduce drag during high speed operation. A still further refinement consists of the addition of a remotely steerable and powered propeller at the outer end of the floating exhaust system. This could be used to hold the system at a particular orientation with respect to the ship when the ship is stopped or moving at a low velocity. In all cases joints **27** may be replaced by universal joints such as shown at **12**. In an alternate embodiment hinges **27** are alternately arranged on vertical and horizontal alignments to provide lateral as well as vertical bending.

While the invention has been described in part with reference to specific embodiments, it will be obvious to those skilled in the art that modifications and variations may be made without departing from the spirit and scope of the invention.

The scope of the invenion is defined in the following claims.

I claim:

1. A floating exhaust system comprising a source of gaseous exhaust, a conduit connected to the source for conducting exhaust from the source, a generally horizontal floating stack connected to the conduit for receiving exhaust from the conduit, support means connected to the stack for supporting the stack on a generally horizontal body of water and outlet means connected to a distal end of the stack remote from the conduit for flowing exhaust out of the stack.

2. The floating exhaust system of claim **1** further comprising a source of water pressure, a water pipe connected to the source of water pressure and connected to the conduit and stack for carrying water to the conduit and stack and spray heads mounted in the water pipe for spraying water into the exhaust chamber within the conduit and stack for washing particulate matter from the exhaust and for cooling and condensing the exhaust.

3. The floating exhaust system of claim **2** further comprising flexible water pipes interconnecting rigid water pipes between sections of the stack.

4. The floating exhaust system of claim **2** wherein the pipes are mounted in a lower position in the stack and support means for stabilizing the stack.

5. The floating exhaust system of claim **1** wherein the generally horizontal stack comprises a plurality of sections and hinges joining the sections whereby the stack adjusts to disruptions in the surface of a body on which it is supported.

6. The apparatus of claim **5** wherein the hinges are transverse to an elongated direction of the stack and are generally horizontal, and wherein the stack sections further comprise overlapping sides for preventing laterally outward flow of exhaust gases between the sections.

7. The floating exhaust system of claim **1** wherein the support means comprise elongated generally parallel floats and wherein the stack means comprises an arched cover generally interconnecting the floats, thereby forming an exhaust chamber between the cover and the floats and an open surface between the floats of the body on which the floats are supported.

8. The apparatus of claim **7** wherein the floats and cover comprise generally parallel vertical displacement portions and a roof interconnecting the portions.

9. The floating exhaust system of claim **1** wherein the stack comprises a plurality of elongated tubular sections and wherein the support means comprises individual supporting means mounted beneath the tubular sections.

10. The floating exhaust system of claim **9** wherein the individual supporting means comprises floats at ends of the sections and further comprising downward openings between tube sections intermediate the floats for permitting washing of water in and out of the sections to remove particulate material.

11. The floating exhaust system of claim **1** wherein the conduit comprises a universal joint connecting the source of exhaust and the stack, whereby the stack may be turned about the source of exhaust.

12. The floating exhaust system of claim **1** wherein the outlet means comprises an opening in the distal end with a filter in the opening and means to wash the filter.

13. The apparatus of claim **12** wherein the opening is downward pointing.

14. The apparatus of claim **12** further comprising pressure release means at the distal end of the stack for releasing excessive fluid pressure within the stack.

* * * * *

Exhibit 9

US005632660A

United States Patent [19]

[11] Patent Number: 5,632,660

[45] Date of Patent: May 27, 1997

Nakase et al.

[54] **WATERCRAFT CATALYTIC EXHAUST SYSTEM**

[75] Inventors: **Ryoichi Nakase; Shigeyuki Ozawa; Hiroaki Fujimoto**, all of Hamamatsu, Japan

[73] Assignee: **Sanshin Kogyo Kabushiki Kaisha**, Hamamatsu, Japan

[21] Appl. No.: **484,953**

[22] Filed: **Jun. 7, 1995**

[30] **Foreign Application Priority Data**

Feb. 27, 1995	[JP]	Japan	7-038150
Feb. 27, 1995	[JP]	Japan	7-038161
Feb. 27, 1995	[JP]	Japan	7-038168

[51] **Int. Cl.**^{6} **B63H 21/32**

[52] **U.S. Cl.** **440/89**; 60/310

[58] **Field of Search** 440/89, 88; 114/270; 60/320, 321, 322

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,664,054	5/1987	Nishida	114/270
4,773,883	9/1988	Nakase et al.	440/89
4,811,560	3/1989	Nakase et al. .	
4,982,682	1/1991	Hattori	440/89
4,989,409	2/1991	Nakase et al. .	
4,997,399	3/1991	Nakayasu et al. .	
5,067,448	11/1991	Nakase et al. .	
5,096,446	3/1992	Tazaki et al. .	
5,234,364	8/1993	Ito .	
5,251,439	10/1993	Nakase et al. .	
5,324,217	6/1994	Mineo	440/89
5,366,401	11/1994	Nanami et al.	440/89
5,408,827	4/1995	Holtermann et al.	60/298
5,511,505	4/1996	Kobayashi et al.	440/89

FOREIGN PATENT DOCUMENTS

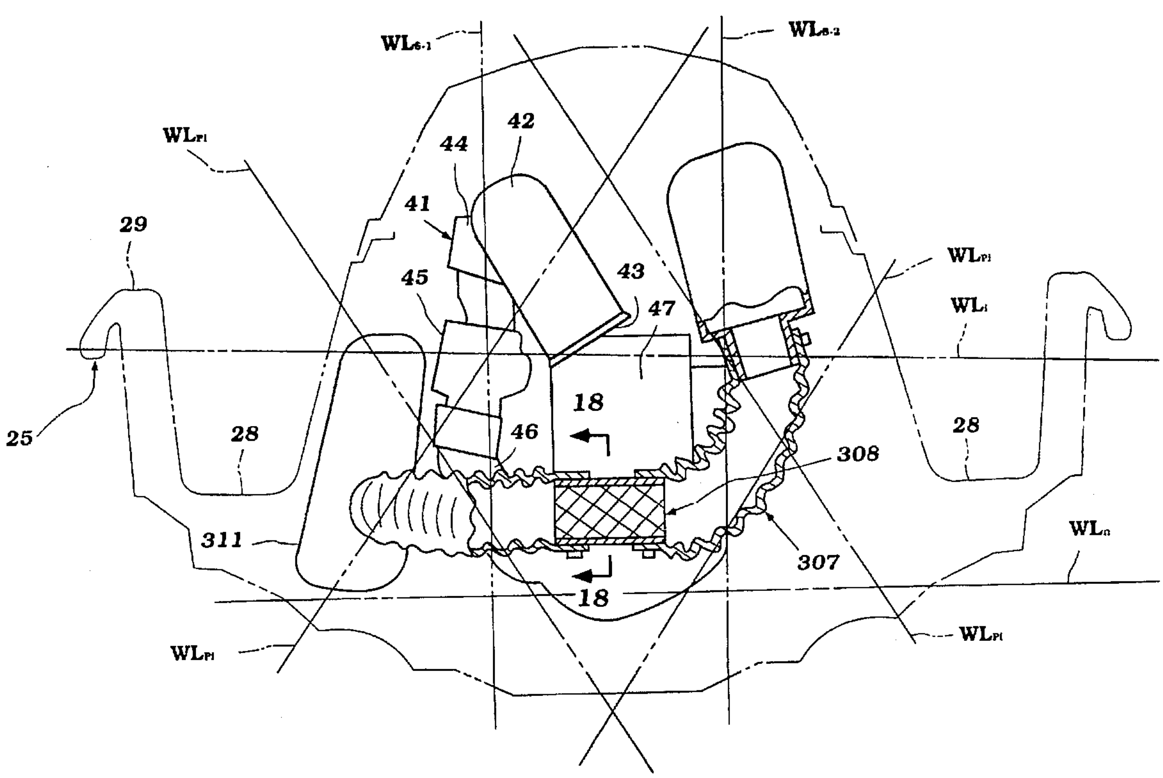
2256814	10/1990	Japan .

Primary Examiner—Jesus D. Sotelo
Attorney, Agent, or Firm—Knobbe, Martens, Olson & Bear, LLP

[57] **ABSTRACT**

A number of embodiments of personal watercraft having catalytic exhaust systems for treating and purifying the exhaust gases. In all of the embodiments, the catalyst is positioned and disposed so as to be protected from water. In addition, arrangements are provided for cooling the catalyst, for circulating ventilating air across it, for isolating it from other components such as the fuel tank, and for permitting its flushing with fresh water after operating in a salt water environment.

21 Claims, 18 Drawing Sheets



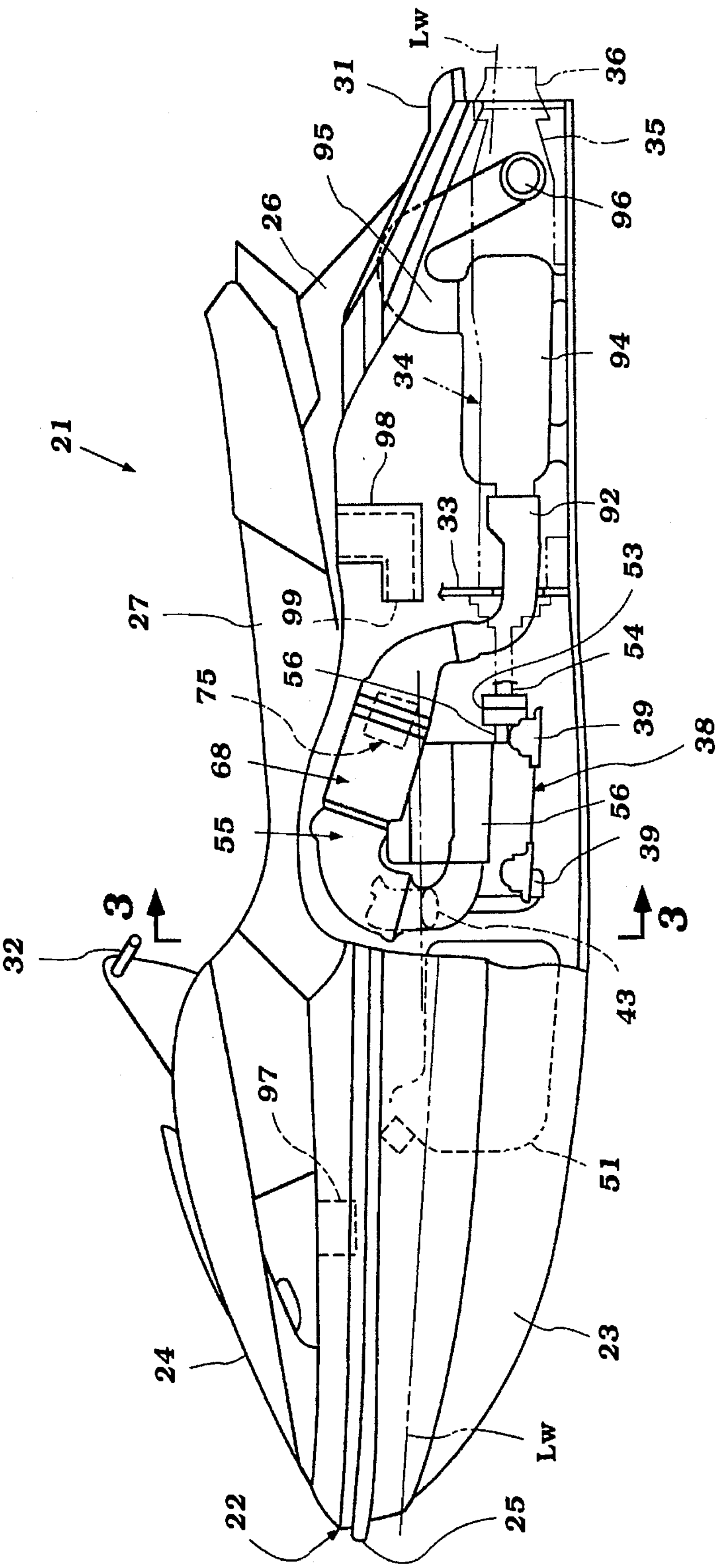


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Figure 1

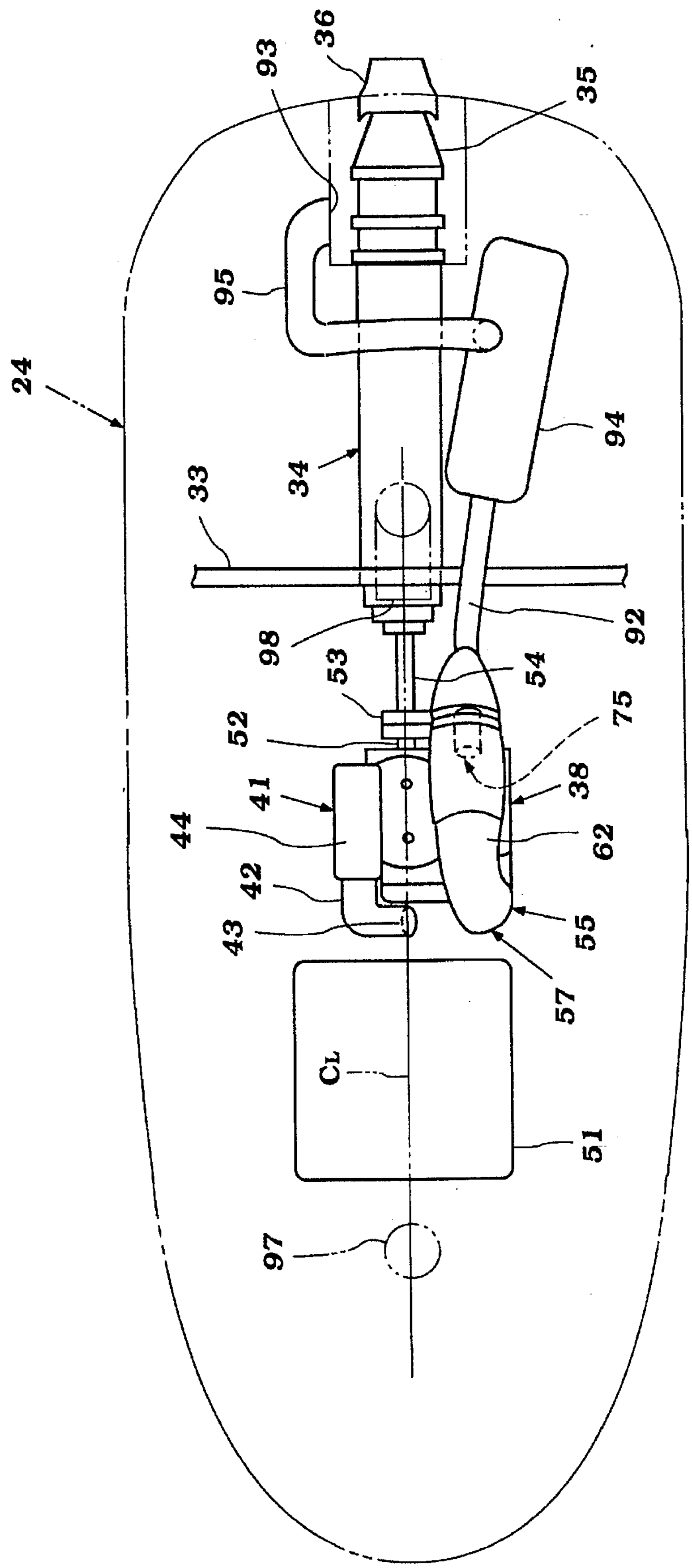

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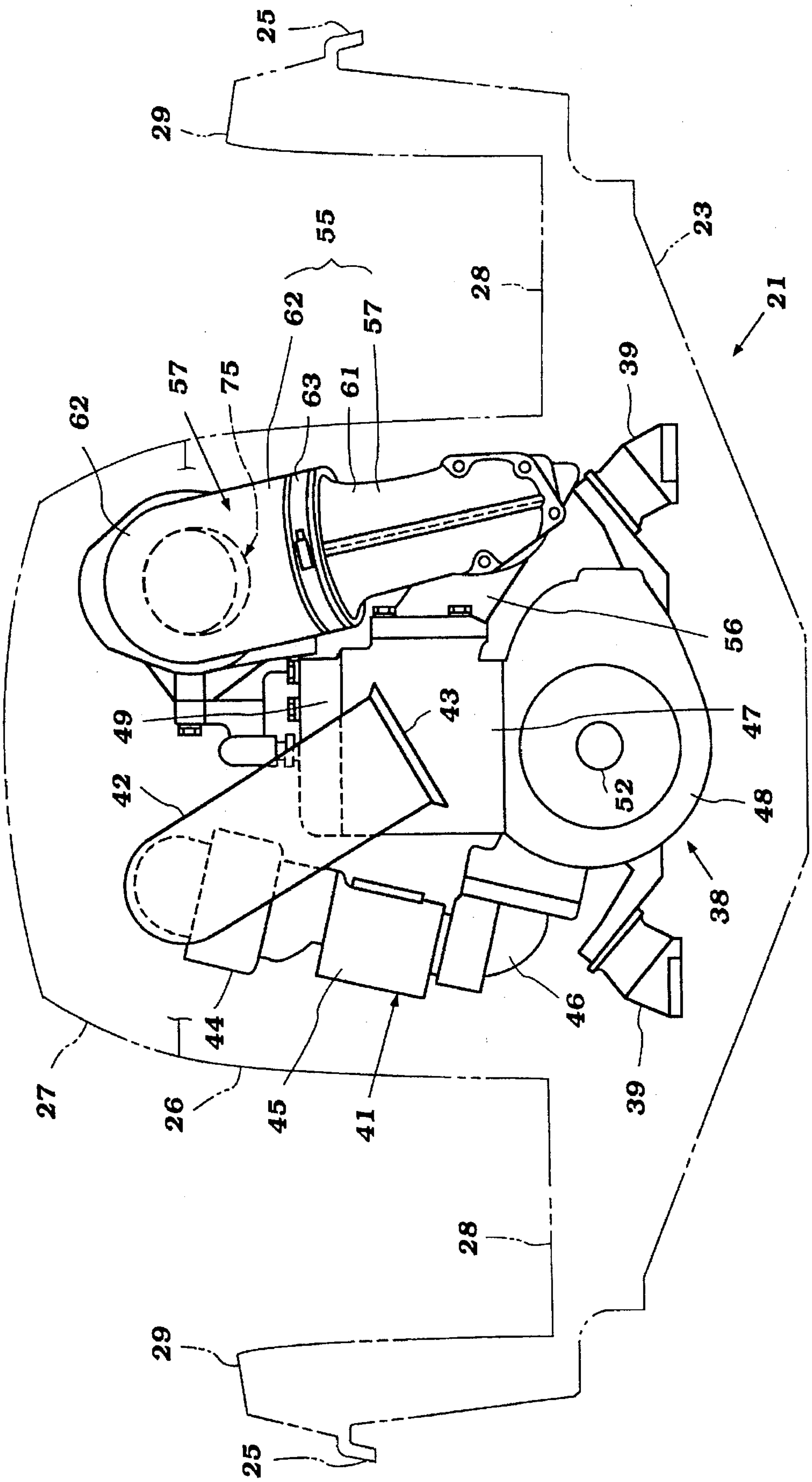
Figure 2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63
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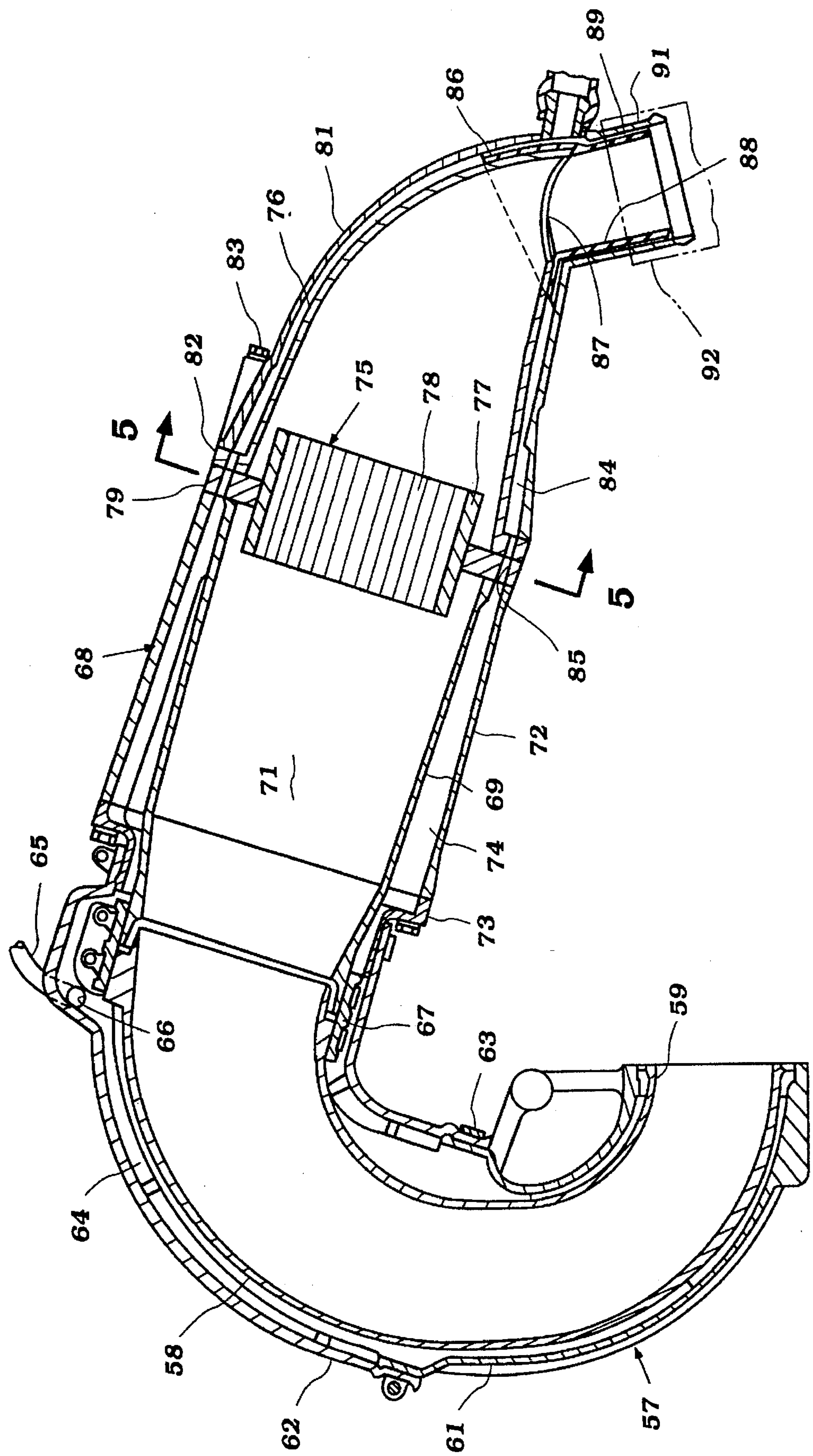
25

Figure 3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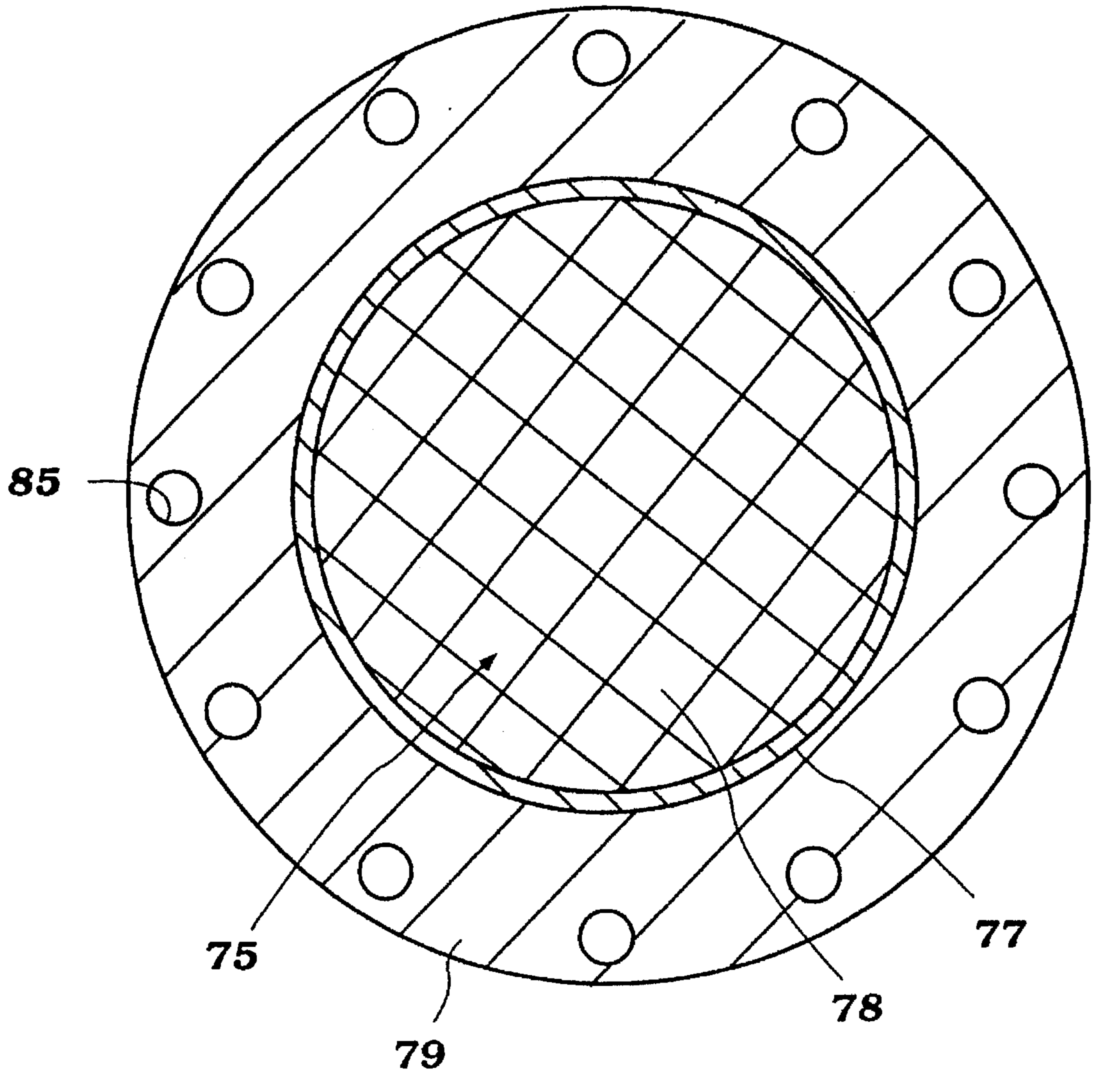
61
57

Figure 4



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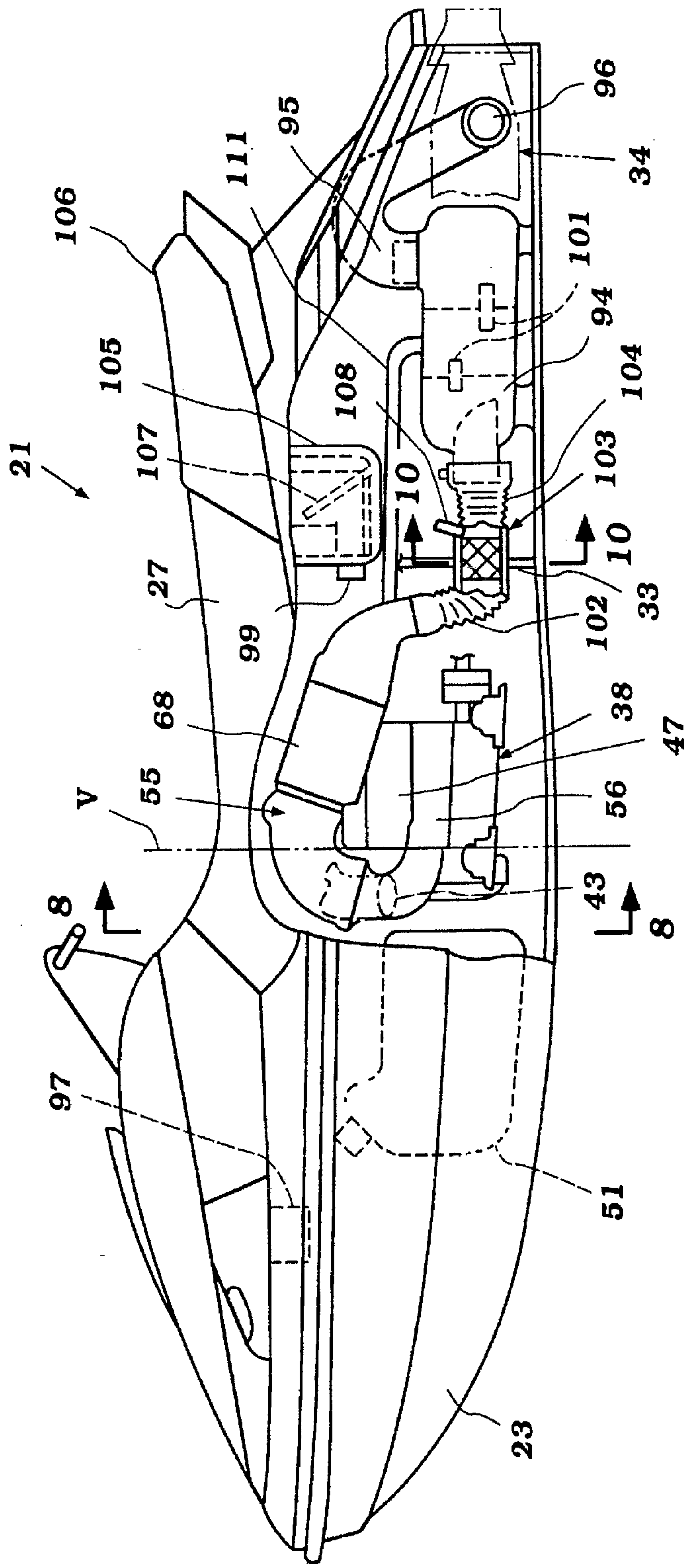
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38
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V
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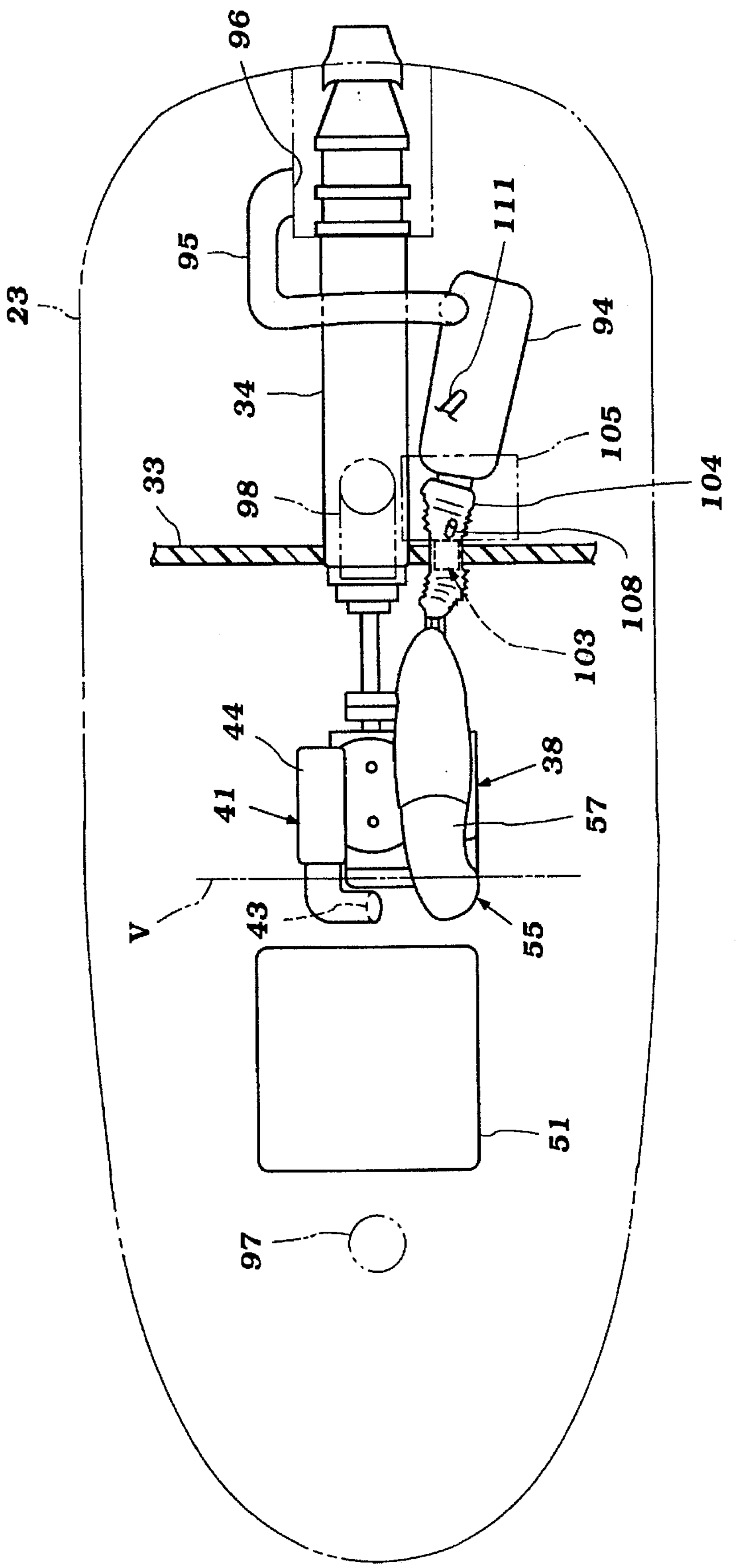
43
8
97
51
23

Figure 6



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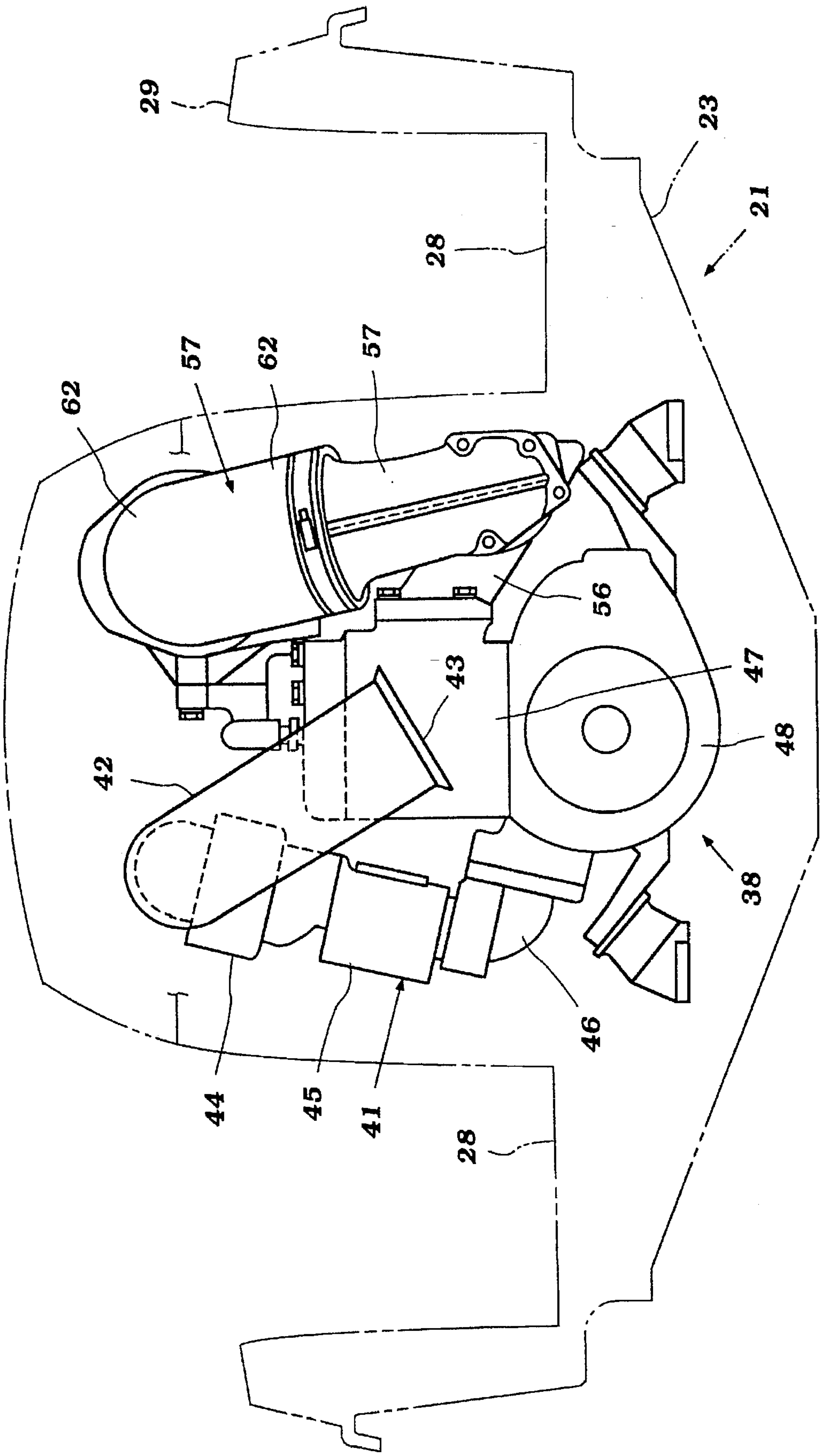
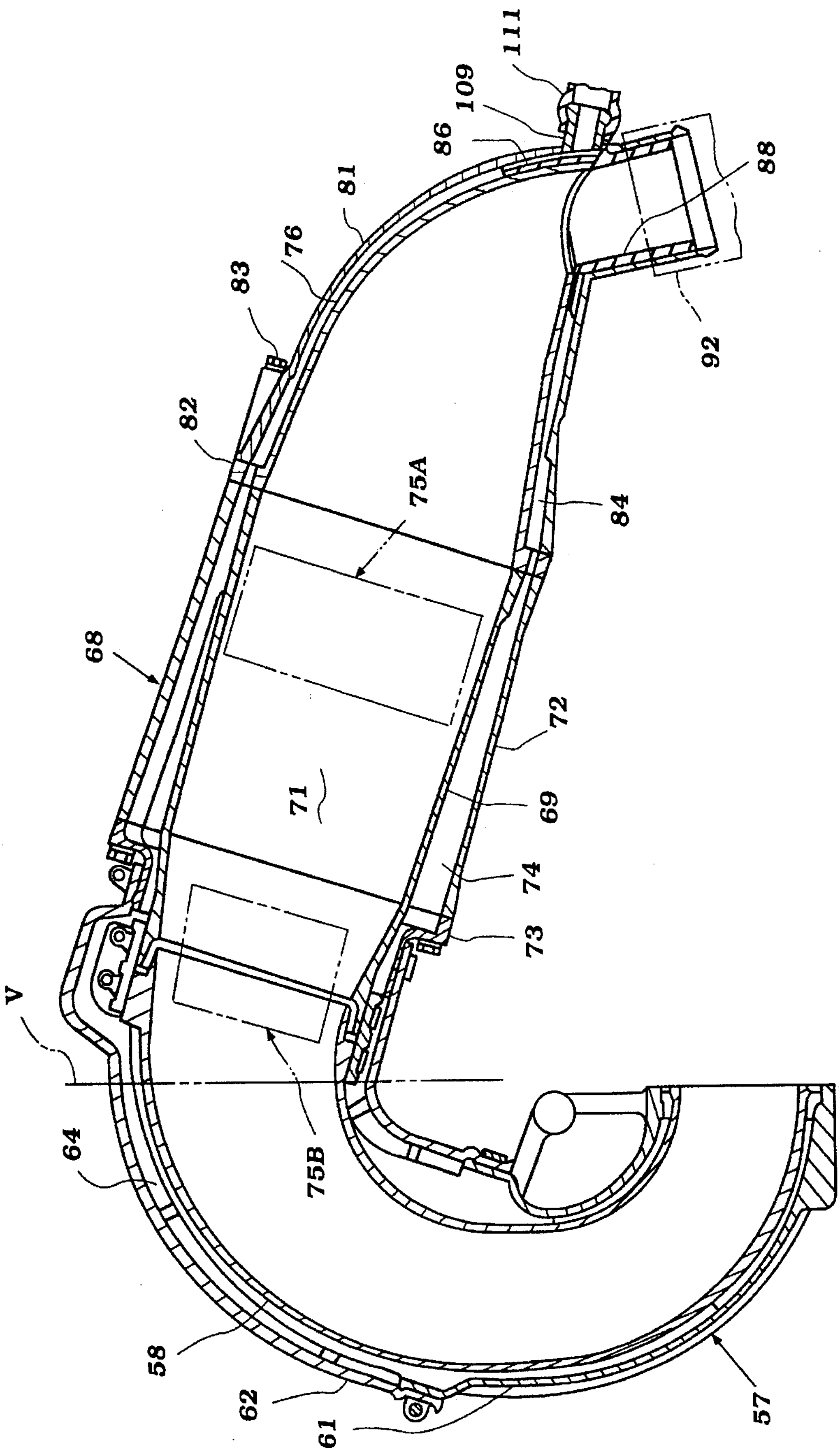


Figure 8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71
69
74
73
V
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75B
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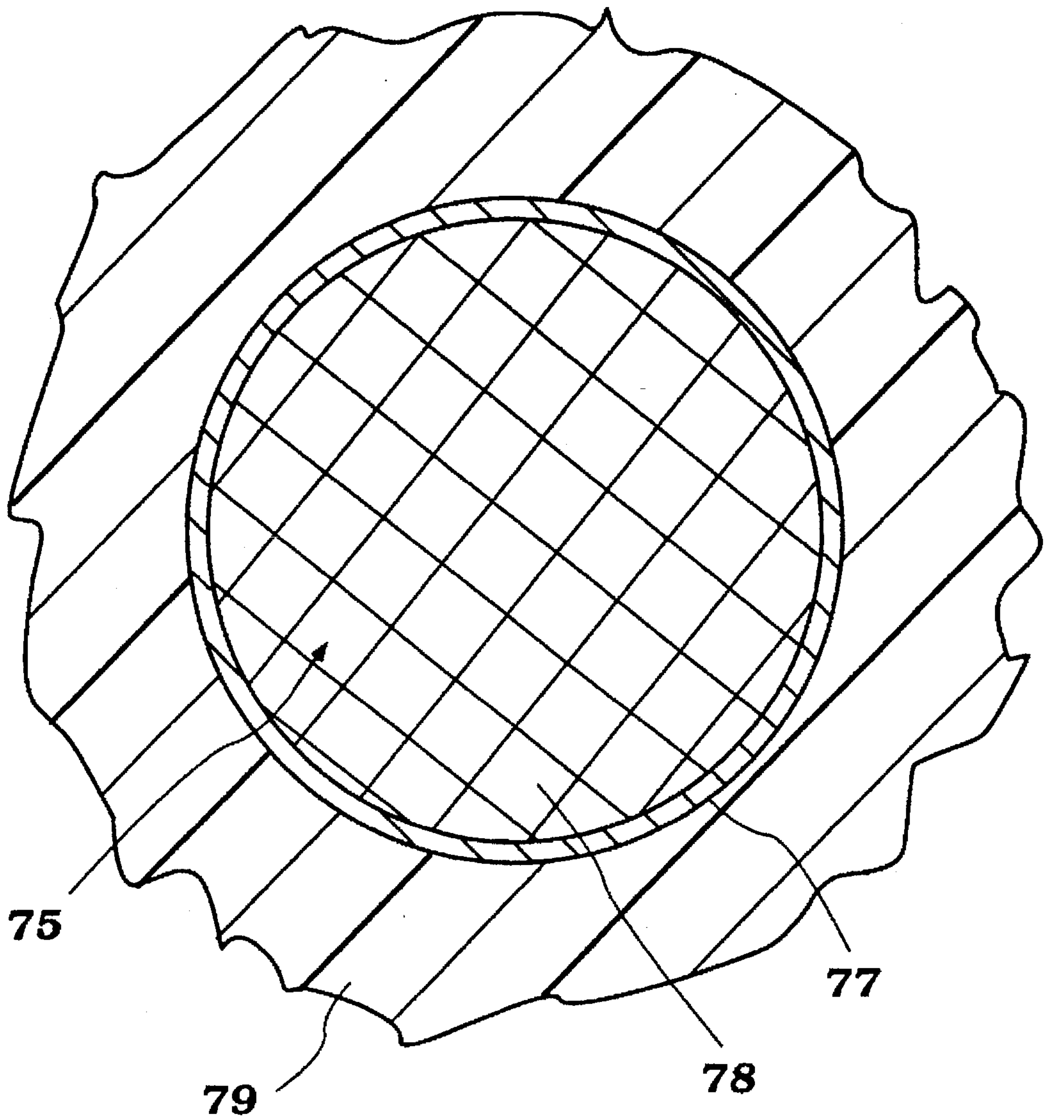
62
61
57

Figure 9



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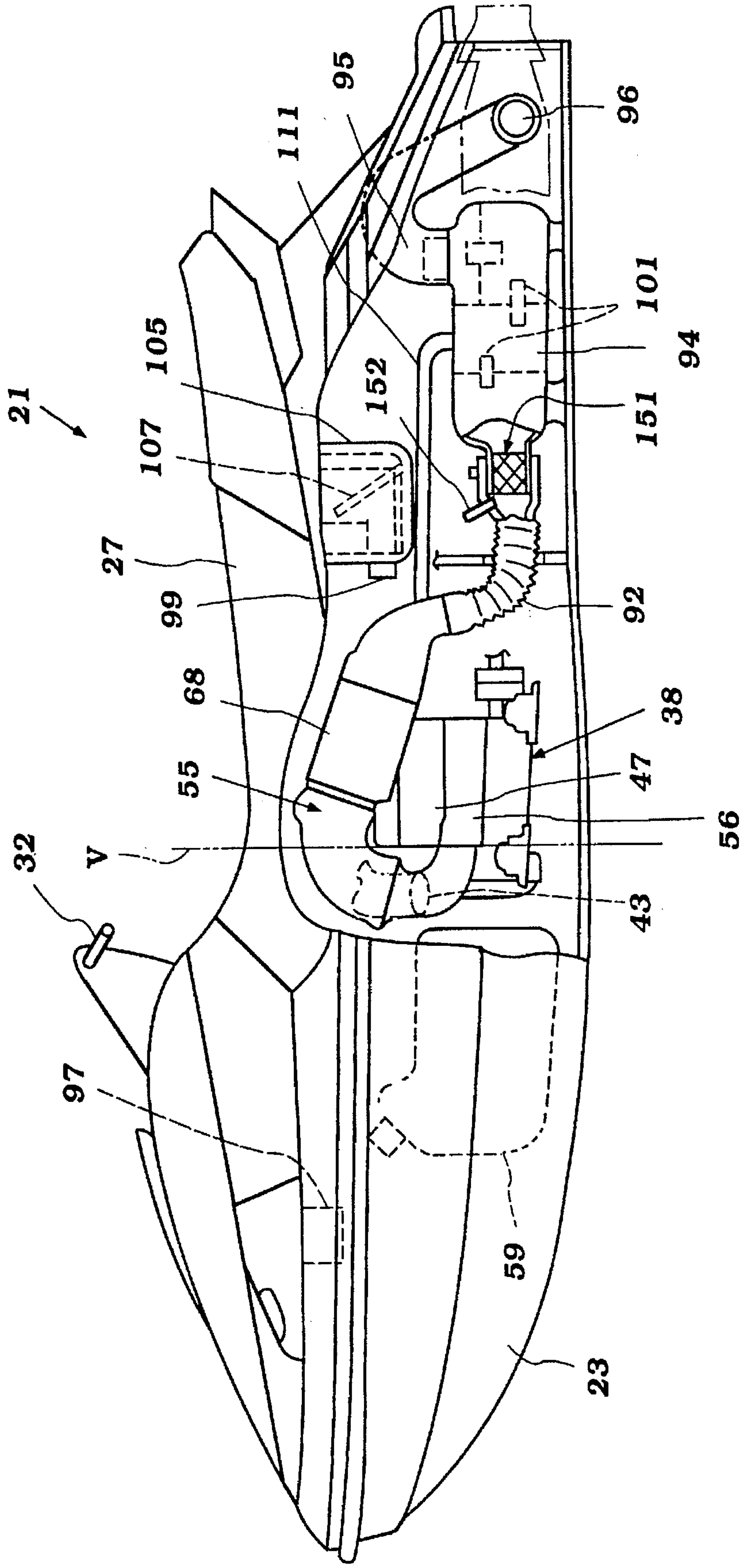
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111
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56
V
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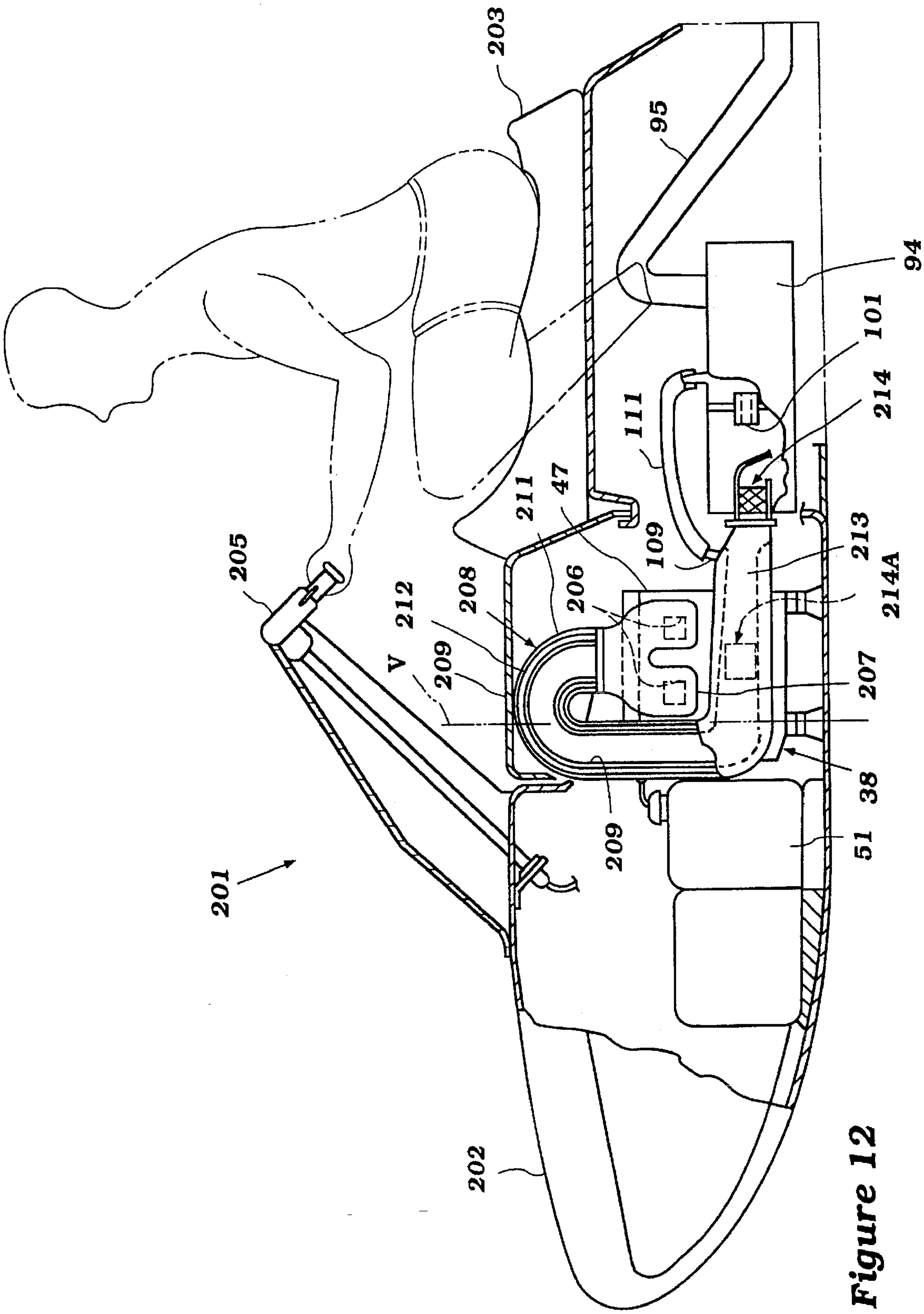
43
97
59
23

Figure 11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206
V
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207
38
51
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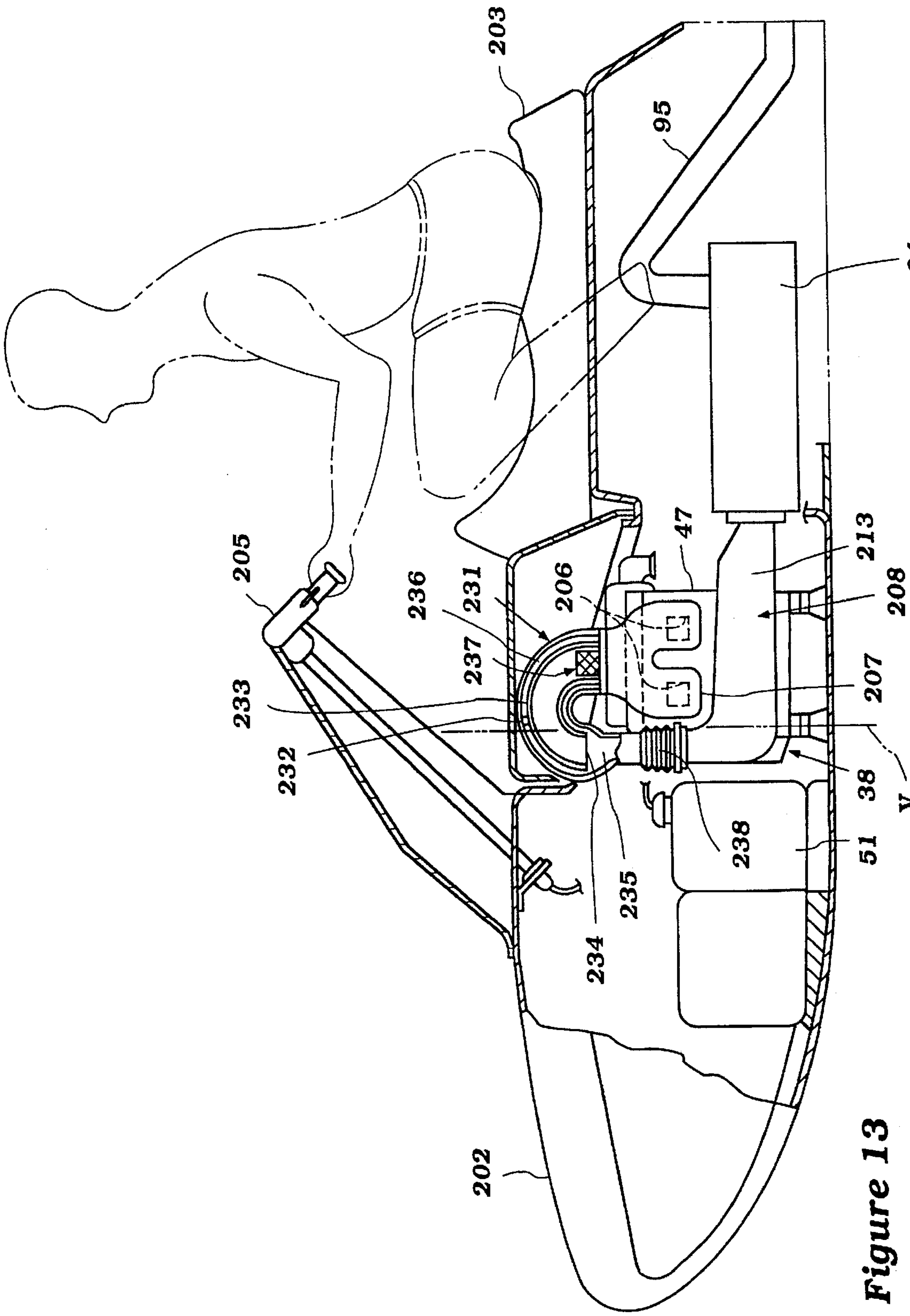
201
202

Figure 12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202

Figure 13

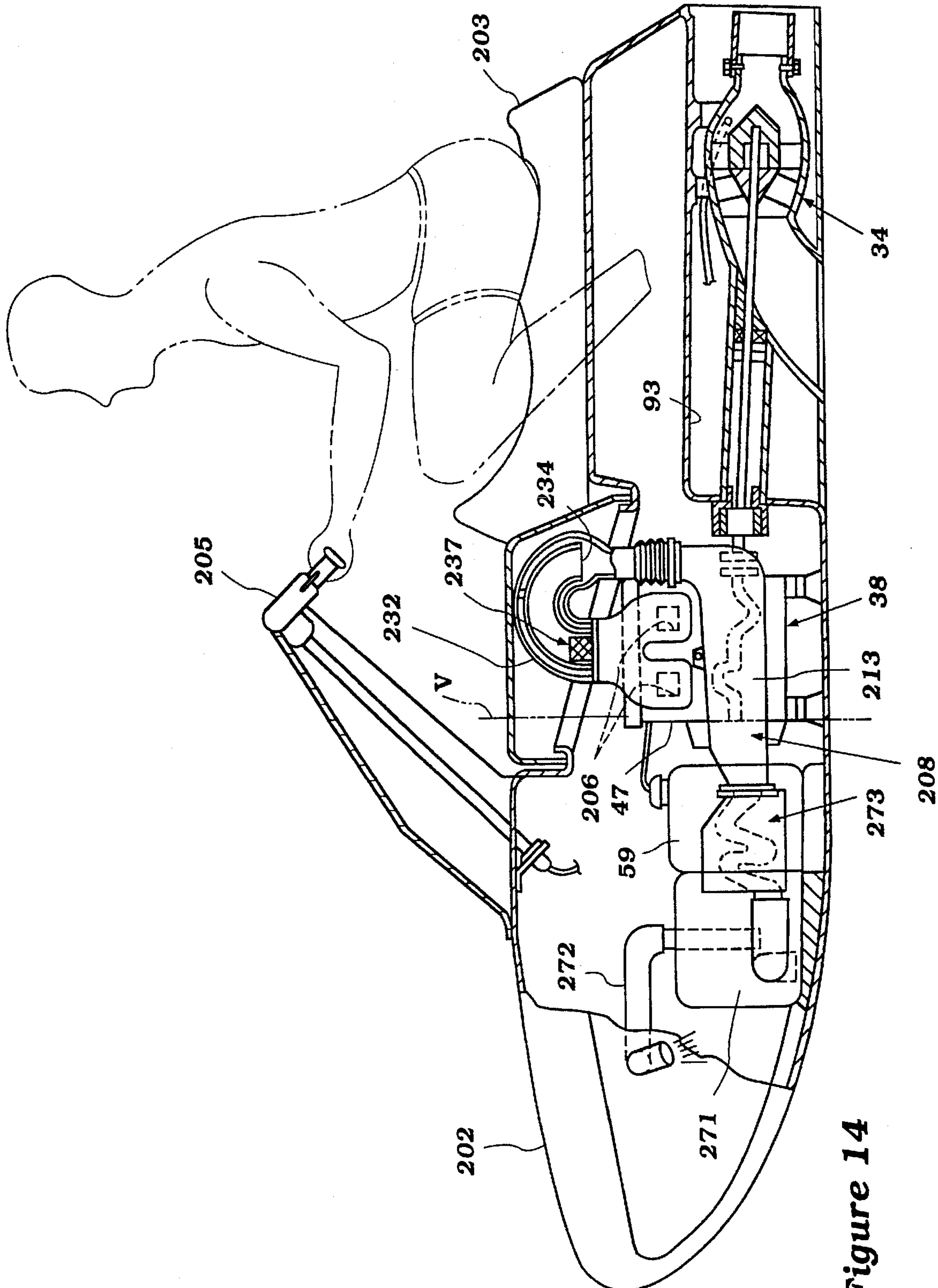
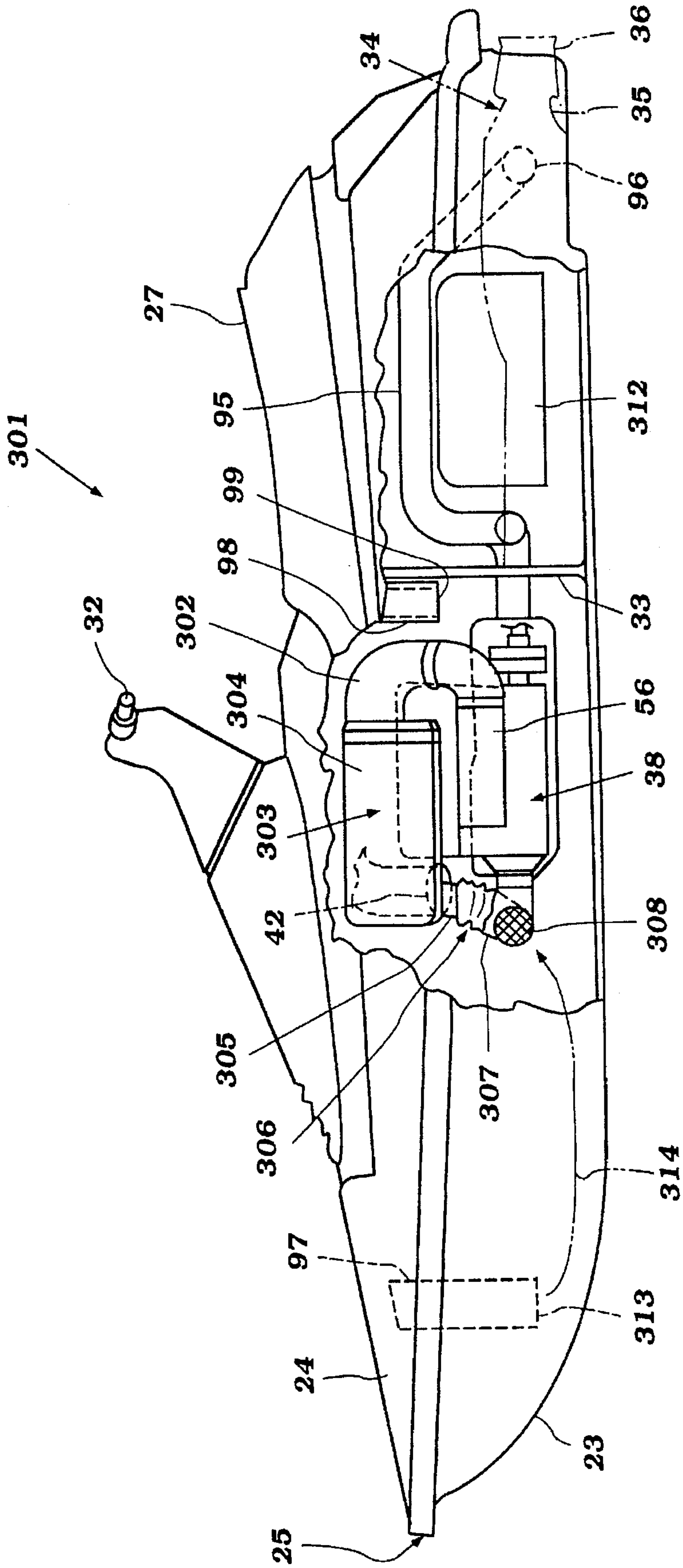


Figure 14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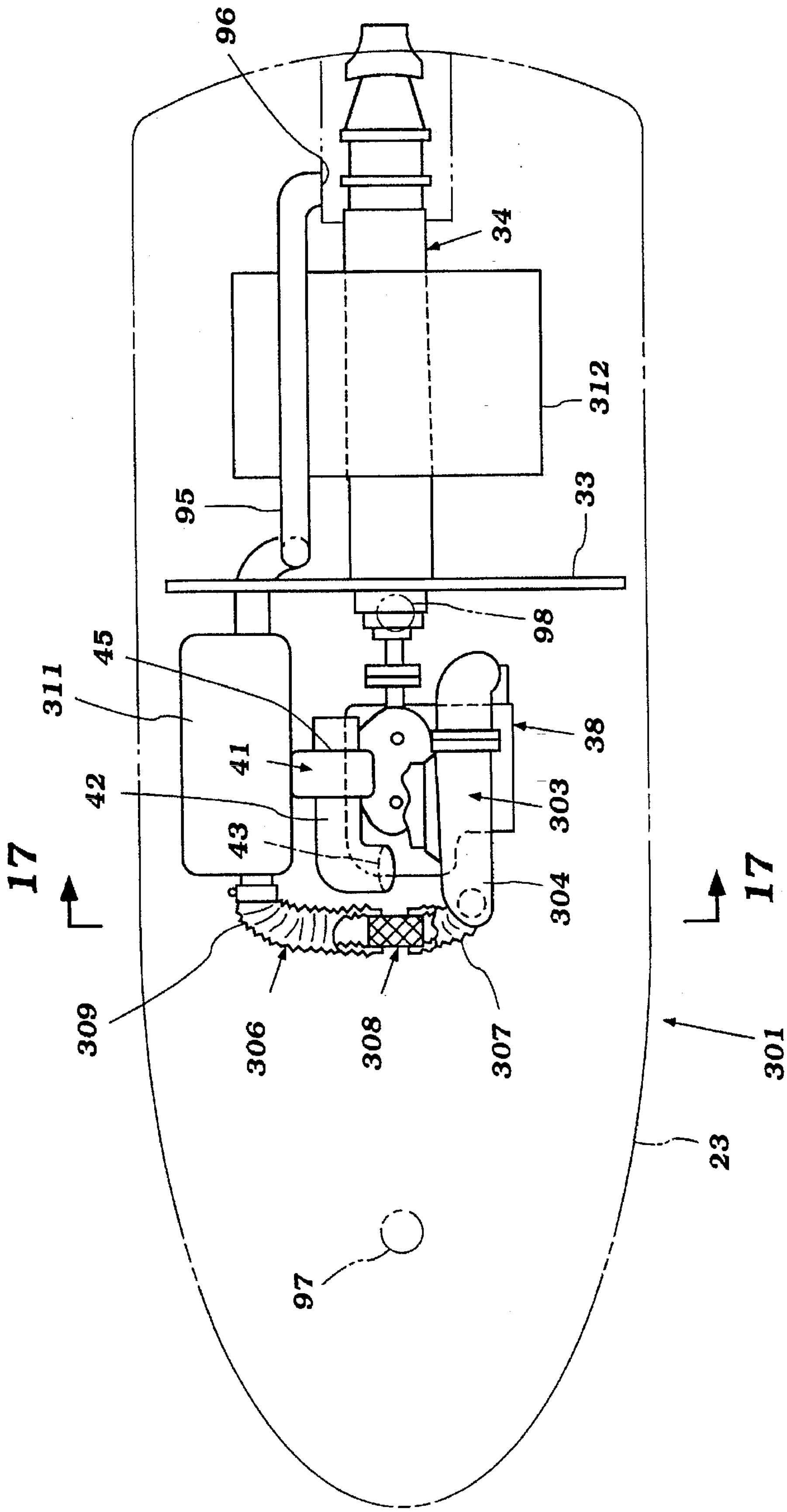
25

Figure 15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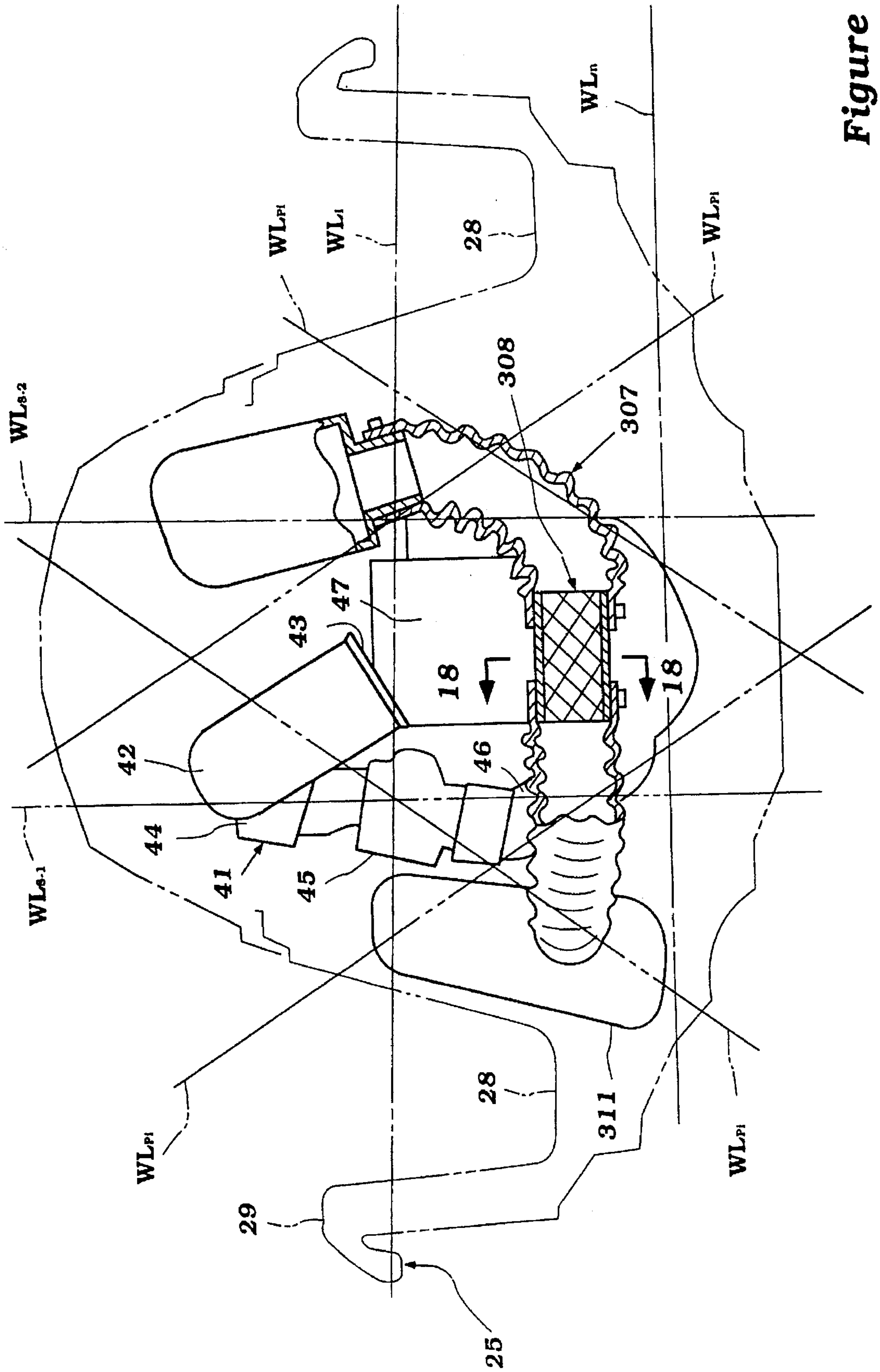
97

Figure 16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WLP1
WL1
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WLP1
WL8-2
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46
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41
45
WL8-1
311
28
WLP1
WLP1
29
25

Figure 17

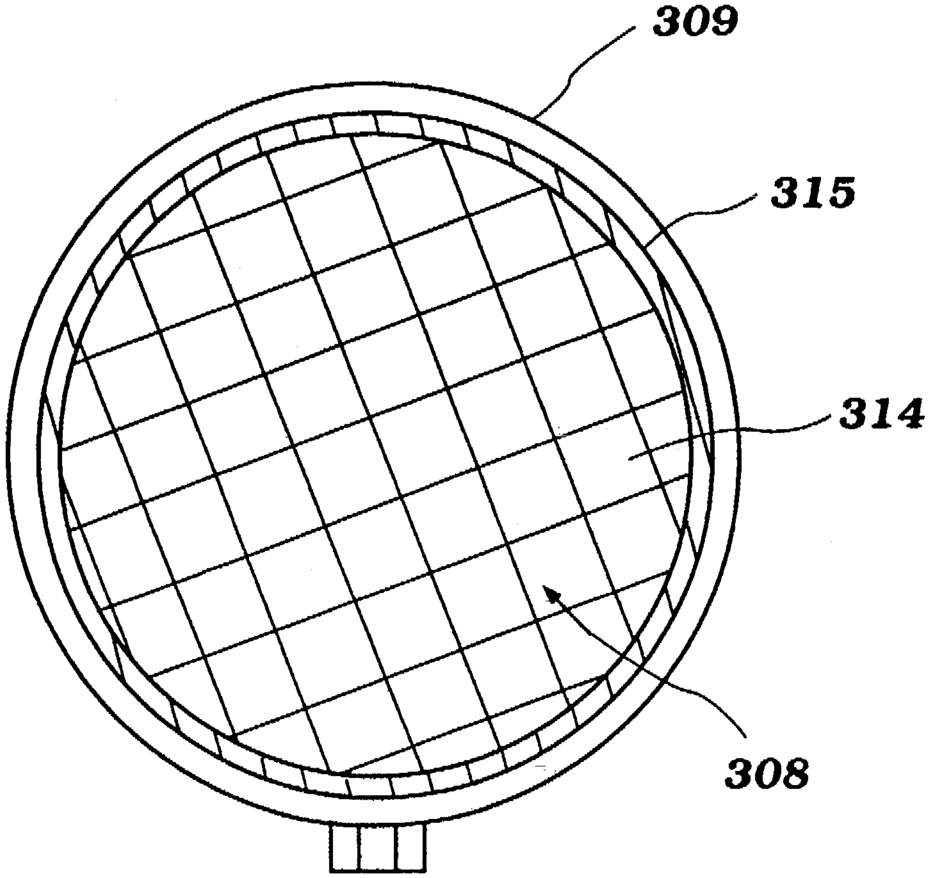

Figure 18

WATERCRAFT CATALYTIC EXHAUST SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to an exhaust system for a personal watercraft and more particularly to a catalytic exhaust system for such watercraft.

There is a very popular and growing segment of the watercraft market for a type of watercraft called a "personal watercraft." This type of watercraft is comprised of a relatively small hull that defines a rider's area which is designed primarily to accommodate a rider and possibly one or two additional passengers. This type of watercraft is generally quite sporting in nature, and the watercraft may at times become inverted or at least partially capsized. In addition, it is frequently the situation that the rider and/or passengers may enter the watercraft from the body of water in which the watercraft is operating. Therefore, it is common for the rider and passengers to wear swimming suits when operating this type of watercraft.

Frequently, this type of watercraft is powered by a jet propulsion unit which is mounted in a tunnel to the underside of the hull, and thus the watercraft provides a very neat and compact appearance. The propulsion unit is frequently a two-cycle internal combustion engine because of the small size and high output of these engines.

As is well known with many types of watercraft, the exhaust gases from the watercraft engine are discharged to the atmosphere either through or close to the body of water in which the watercraft is operating. Thus, environmental concerns raise a desire to ensure that the exhaust gases are relatively clean so as to avoid pollution of not only the atmosphere, but also of the water body. These problems are particularly acute in connection with two-cycle engines because of the fact that frequently the exhaust products contain lubricant and other hydrocarbons.

It is, therefore, a principal object of this invention to provide an improved exhaust system for this type of watercraft.

It is a further object of this invention to provide an exhaust system for a personal watercraft wherein a catalyst is provided in the exhaust system for treating the exhaust gases and removing objectionable exhaust gas constituents.

From the foregoing description it should be readily apparent that the sporting nature of this type of watercraft means that water can, from time to time, enter the exhaust system. This is particularly true when the watercraft is operating with its discharge either at or below the water level. The problem becomes particularly acute in the event the watercraft becomes inverted and is subsequently righted.

As is well known, catalysts operate at a relatively high temperature in order to become efficient. If a large body of water is permitted to come into contact with the catalyst, for example, during the capsizing and righting operation aforenoted, the catalyst bed may become shattered. Even if the bed does not shatter, the water contacting it may cause pollution of the catalyst, particularly when operating in marine environments.

It is a further object of this invention to provide an improved catalytic exhaust system for a personal watercraft wherein the catalyst is positioned so that it will be protected from damage by water.

In addition to the problems of possible water damage or water contamination, the temperature at which the catalyst operates makes it desirable to ensure some arrangement for protecting the surrounding environment in the hull from the heat of the catalyst. This is particularly important with small personal watercraft because of the fact that the engine compartment is relatively small and also because of the fact that the size of the watercraft requires the various components and auxiliaries to be placed close to each other.

It is, therefore, a still further object of this invention to provide an improved arrangement for protecting the surroundings in a personal watercraft from the heat of a catalyst in its exhaust system.

Frequently, it is the practice to encircle at least a portion of the exhaust system such as the exhaust manifold and/or expansion chamber with a cooling jacket through which engine coolant is circulated. This helps not only to silence the exhaust gases, but also to offer protection to the surrounding environment. The water which has passed through the cooling jacket is then generally dumped back into the exhaust system so as to further cool it and to assist in its discharge back to the body of water in which the watercraft is operating. This added water to the exhaust system gives a rise to possible damage to the catalyst, for reasons noted above.

It is, therefore, a still further object of this invention to provide an improved exhaust system for a personal watercraft wherein the exhaust system is provided with a cooling jacket and water is returned from this cooling jacket to the exhaust system but in a way so as to protect a catalyst in the exhaust system from damage.

It is a further object of this invention to provide an improved catalytic exhaust system for a personal watercraft wherein the catalyst is positioned in such a way that it can be easily cooled.

It is a still further object of this invention to provide an improved catalytic exhaust system for a personal watercraft wherein the catalyst is disposed so that it is spaced from other components or auxiliaries of the engine which might be prone to damage from heat.

As has been previously noted, one problem attendant with the provision of catalytic exhaust systems for personal watercraft is the danger of water damage. As has been previously noted, this type of watercraft may become inverted or partially capsized, and upon this condition or upon subsequent righting there is a danger than the water may come into contact with the catalyst.

It is, therefore, a still further object of this invention to provide an improved catalytic exhaust system for a personal watercraft wherein the catalyst and exhaust system is arranged in such a way that the catalyst will always be at a high point, regardless of the orientation of the watercraft, so as to reduce the likelihood of water reaching it.

Although it is desirable to protect the catalyst from contact with water when the engine is running, there may be sometimes when it is desirable to be able to flush the catalyst bed with clear water for cleaning purposes. That is, although the catalyst should not contact the water when the catalyst is at a high temperature and the water is at a lower temperature, there may be containments that are deposited on the catalyst bed. It may be desirable to employ a water flushing arrangement for clearing these contaminants from the catalyst bed.

For example, if the watercraft is operating in a marine environment, the presence of water or water vapor in the exhaust system can give rise to the condensation or deposition of the water born contaminants such as salt on the catalyst bed. Once the watercraft is taken out of operation, it may be desirable to have an arrangement wherein the catalyst bed may be flushed with pure water to remove these deposited contaminants.

It is, therefore, a still further object of this invention to provide an improved arrangement for flushing the catalyst in a watercraft exhaust system.

SUMMARY OF THE INVENTION

One feature of this invention is adapted to be embodied in a personal watercraft having a hull that defines a rider's area that is sized to accommodate at least one rider and which is configured and arranged so that a rider may easily enter the rider's area from the body of water in which the watercraft is operating. The hull defines an engine compartment that contains an internal combustion engine having at least one exhaust port and an output shaft. A propulsion device is carried by the hull and is driven by the engine output shaft for propelling the watercraft. An exhaust system conveys exhaust gases from the engine exhaust port to the atmosphere at a position contiguous to the water level. A catalyst is provided in the exhaust system for treating the exhaust gases before discharge to the atmosphere.

Another feature of the invention is also adapted to be embodied in a personal watercraft having a hull that defines a rider's area which is sized to accommodate at least one rider. The hull defines an engine compartment that contains an internal combustion engine having at least one exhaust port and an output shaft. A propulsion device is carried by the hull in an under portion thereof and which is driven by the engine output shaft for propelling the watercraft. An exhaust system is provided for conveying exhaust gases from the engine exhaust port to the atmosphere at a point contiguous to the water level when the watercraft is operating in a body of water. A catalyst is positioned in the exhaust system for treating the exhaust gases before discharge to the atmosphere. A water trap device is disposed in the exhaust system for trapping water which may tend to flow to the catalyst from the exhaust outlet.

Another feature of the invention is adapted to be embodied in a personal watercraft having a hull defining a rider's area that is sized to accommodate at least one rider. The hull defines an engine compartment that contains an internal combustion engine having at least one exhaust port for discharging exhaust gases and an induction system having an induction system air inlet. The engine also has an output shaft. This output shaft drives a propulsion device that is carried by the hull on the underside thereof for propelling the watercraft. An exhaust system conveys exhaust gases from the engine exhaust port to the atmosphere at a point contiguous to the water level when the watercraft is operating in a body of water. A catalyst is positioned in the exhaust system for treating the exhaust gases before discharge to the atmosphere. This catalyst is disposed above both the induction system air inlet and the exhaust port.

A still further feature of the invention is also adapted to be embodied in a personal watercraft that has a hull defining a rider's area that is sized to accommodate at least one rider. The hull defines an engine compartment containing an internal combustion engine and having at least one exhaust port and an output shaft. A propulsion device is carried by the hull and is driven by the engine output shaft for propelling the watercraft. A ventilating system is provided for circulating ventilating air through the engine compartment. An exhaust system is provided for conveying exhaust gases from the engine exhaust port to the atmosphere. A catalyst is positioned in the exhaust system for treating the exhaust gases before discharge to the atmosphere. This catalyst is disposed so that it will be in the path of the ventilating air flow through the engine compartment.

A still further feature of the invention is also adapted to be embodied in a personal watercraft having a hull that defines a rider area that is sized to accommodate at least one rider. The hull defines an engine compartment that contains an internal combustion engine which has at least one exhaust port and an output shaft. A propulsion device is carried by the hull and is driven by the engine output shaft for propelling the watercraft. An exhaust system is provided for conveying exhaust gases from the engine exhaust port to the atmosphere at a point contiguous to the water level when the watercraft is floating in a body of water. A catalyst is disposed in the exhaust system for treating the exhaust gases before their discharge to the atmosphere. This catalyst is disposed in a location so that it will be above the water level at any time the watercraft is floating in a body of water and regardless of the orientation at which the watercraft is floating be it erect or inverted.

Yet another feature of the invention is adapted to be embodied in a watercraft having a hull that defines a rider's area for accommodating at least one rider. The hull defines an engine Compartment that contains an internal combustion engine which has at least one exhaust port and an output shaft. A propulsion device is carried by the hull and is driven by the engine output shaft for propelling the watercraft. An exhaust system is providing for conveying exhaust gases from the exhaust port to the atmosphere. A catalyst is disposed in the exhaust system for treating the exhaust gases before their discharge to the atmosphere. A flushing port is positioned in the exhaust system contiguous to the catalyst so that the catalyst bed may be flushed with pure water when the watercraft is not being operated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view, with a portion broken away, Of a personal watercraft constructed in accordance with a first embodiment of the invention.

FIG. **2** is a top plan view of the watercraft with the hull shown in phantom, except for the bulk head that defines the forward end of the tunnel in which the propulsion unit is contained so as to show the orientation of the engine, its auxiliaries, and the propulsion system.

FIG. **3** is an enlarged cross-sectional view taken along the line **3**—**3** of FIG. **1**, but shows the hull in phantom.

FIG. **4** is an enlarged cross-sectional view taken through the exhaust expansion chamber device of this embodiment.

FIG. **5** is a further enlarged cross-sectional view taken along the line **5**—**5** of FIG. **4** and shows the catalyst bed and its support.

FIG. **6** is a side elevational view, with a portion broken away, in part similar to FIG. **1** and shows another embodiment of the invention.

FIG. **7** is a top plan view, in part similar to FIG. **2**, but shows this embodiment in a similar manner.

FIG. **8** is a cross-sectional view, in part similar to FIG. **3**, but taken along the line **8**—**8** of FIG. **6**.

FIG. **9** is an enlarged cross-sectional view, in part similar to FIG. **4**, and shows the expansion chamber device of this embodiment.

FIG. **10** is a further enlarged cross-sectional view taken along the line **10**—**10** of FIG. **6** and shows the catalyst bed and its support for this embodiment.

FIG. **11** is a side elevational view, with a portion broken away in part similar to FIGS. **1** and **6**, and shows a third embodiment of the invention.

FIG. **12** is a side elevational view, with a portion broken away in part similar to FIGS. **1**, **6**, and **11**, and shows a fourth embodiment of the invention.

FIG. **13** is a side elevational view, with a portion broken away in part similar to FIGS. **1**, **6**, **11**, and **12**, and shows a fifth embodiment of the invention.

FIG. **14** is a side elevational view, with a portion broken away in part similar to FIGS. **1**, **6**, **11**, **12**, and **13**, and shows a sixth embodiment of the invention.

FIG. **15** is a side elevational view, with a portion broken away in part similar to FIGS. **1**, **6**, **11**, **12**, **13**, and **14**, and shows a seventh embodiment of the invention.

FIG. **16** is a top plan view, in part similar to FIGS. **2** and **7**, showing this embodiment.

FIG. **17** is an enlarged cross-sectional view, in part similar to FIGS. **3** and **8** but taken along the line **17**—**17** of FIG. **16**, for this embodiment.

FIG. **18** is an enlarged cross-sectional view taken along the line **18**—**18** and shows the catalyst bed support for this embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

Referring now in detail to the drawings and initially to the embodiment of FIGS. **1**–**5** and initially primarily to FIGS. **1**–**3** thereof, a small personal watercraft constructed in accordance with this embodiment is identified generally by the reference numeral **21**. The small watercraft **21** is of the type known as a personal-type watercraft and is designed so as to be operated by a single rider and may accommodate one or more passengers. Primarily, the watercraft **21** is configured and particularly its passenger area, as will be described, so that the watercraft can be easily boarded from the body of water in which it is operated. The actual configuration of the watercraft **21** may vary, and the various embodiments show certain examples of configurations which may be employed. Of course, those skilled in the art will readily understand how the invention can be practiced with a wide variety of types of watercraft, and particularly personal watercraft.

The watercraft **21** is comprised of a hull, indicated generally by the reference numeral **22**, which is made up primarily of a lower hull portion **23** and an upper deck portion **24**. The portions **23** and **24** are formed from a suitable material such as a molded fiberglass reinforced resin or the like and are connected to each other in any manner known in this art. Normally, the connection is provided at an outstanding flange or gunnel **25** which extends around the peripheral edge of the hull **22**.

The rearward portion of the hull **22** defines a rider's area. A raised pedestal **26** is provided in this rider's area upon which a seat cushion **27** is supported. As may be seen best in FIG. **3**, the area on the sides of the pedestal **26** are provided with foot areas **28** on which riders seated in straddle fashion on the seat **27** may place their feet. In the particular configuration shown in this embodiment, the seat **27** has a length so that it can accommodate the rider/operator and one or two additional passengers.

The outer sides of the foot areas **28** are bounded by raised gunnels **29**. Thus, the riders are protected at the sides by these gunnels **29**. However, the rear of the foot areas **28** open through the rear of the transom of the watercraft so as to facilitate boarding of the watercraft from the rear. In fact, the raised pedestal **25** is disposed forwardly of the rear end of the hull so as to define a rear deck **31** (FIG. **1**) upon which boarding may be made.

The area of the deck **24** forwardly of the seat **27** is provided with a control mast **32** which can be employed for steering of the watercraft in a manner which will be described. In addition, other watercraft controls may be carried by the mast **32**; for example, a throttle control.

The portions **23** and **24** of the hull **22** define a compartment. This compartment serves at least in part as an engine compartment and extends at least in part beneath the seat **27** and terminates at its rear end in a bulk-head **33**. A jet propulsion unit **34** is mounted within a tunnel that is formed in the underside of the hull portion **23** rearwardly of the bulk head **33**. As is typical, this jet propulsion unit **34** is comprised of a water inlet opening which draws water from an opening formed in the underside of the hull portion **23** or in the jet propulsion unit **34** itself via the action of an impeller. The impeller in turn discharges the water rearwardly past straightening vanes to a discharge nozzle portion **35** upon which a steering nozzle **36** is mounted. The steering nozzle **36** is coupled to the mast **32** for its steering about a vertically extending steering axis so as to control the direction of travel of the watercraft. Since the construction of the jet propulsion unit **34** itself forms no part of the invention, it will not be described further. Reference may be had to any of the numerous known prior art devices for the construction which it may take.

Mounted within the engine compartment forwardly of the bulk head **33** and primarily beneath the forward portion of the seat **27** is an internal combustion engine, indicated generally by the reference numeral **38**. The engine **38** may be of any known type and is illustrated in the various embodiments as being of a two-cylinder in-line type operating on a two-stroke crankcase compression principle. It is to be understood that this type of engine is just typical of those with which the invention may be utilized. Those skilled in the art will understand how the invention can be employed with engines having various cylinder numbers and cylinder orientations. The invention also can be utilized in conjunction with four-cycle engines, but it does have particular utility with two-cycle engines because of the unique emission control problems which they present.

The engine **38** is mounted in the hull portion **23** on engine mounts **39** in a manner that is well known in this art. The engine **38** is provided with an induction system which is indicated generally by the reference numeral **41** and which is disposed at one side of the engine on one side of a longitudinally extending center plane CL, which appears in FIG. **2** and certain other figures. This induction system includes an air inlet device **42** which has a generally angular configuration and which forms a downwardly opening air inlet portion **43** which is disposed at the front of the engine **38** within the engine compartment.

The air inlet device **42** supplies air to a plenum chamber **44** which extends along the inlet side of the engine **38** and which delivers the air inducted to charge formers in the form of carburetors **45**. The carburetors **45** in turn deliver the fuel-air charge which they form to an intake manifold **46** that is mounted to a side of a crankcase chamber formed by a cylinder block **47** of the engine and a crankcase member **48** that is affixed to it.

As is well known in two-cycle engine practice, the crankcase chambers of the engine **38** are sealed from each other and communicate with the combustion chamber of the engine defined by the cylinder bores, pistons, and cylinder heads **49** affixed to the cylinder block **47** through scavenge passages. Since the internal details of the engine **38** may be of any conventional type, a further description of the actual engine construction is not believed to be necessary to permit those skilled in the art to understand and practice the invention.

A fuel tank **51** is positioned in the engine compartment forwardly of the engine so that it lies on the longitudinal centerline CL. This fuel tank **51** supplies fuel to the charge formers or carburetors **45** in any known manner.

The engine **38** includes an output shaft **52**, such as a crankshaft, which is journaled within the aforenoted crankcase chamber in any known manner and which extends rearwardly through the end of the engine. A coupling **53** interconnects this engine output shaft **52** with an impeller shaft **54** that extends rearwardly into the jet propulsion unit **34**. The impeller shaft **54** is coupled to the aforenoted impeller in a known manner. Again, this particular detail of the construction of the watercraft **21** is not necessary to understand the construction or operation of the invention. Any conventional structure may be employed.

The exhaust products from the engine **48** are discharged to the atmosphere through an exhaust system, indicated generally by the reference numeral **55**, and which will be described by primary reference to all figures of this embodiment. This exhaust system **55** includes an exhaust manifold **56** that is affixed to the side of the cylinder block **47** and which receives the exhaust gases therefrom through exhaust ports in a well-known manner. This exhaust manifold **56** terminates in a forwardly disposed discharge portion that connects with a C-shaped pipe section, indicated generally by the reference numeral **57**. The pipe section **54** has a construction as best shown in FIGS. **3** and **4**. This section **57** is comprised of an inner tube **58** that has an opening **59** which communicates directly with the discharge end of the exhaust manifold **56**. This inner pipe **58** is surrounded by an outer pipe that is comprised of a lower section **61** and an upper section **62** which are connected to each other through a flexible coupling **63** so as to permit expansion and contraction to accommodate for thermal variations. A water jacket **64** is formed between the inner and outer pipe sections **58**, **61**, and **62** and is held in water-tight relationship by the coupling **63**.

The engine **38** is water cooled, and as is typical in this art, water for cooling purposes is drawn from the body of water in which the watercraft is operating in any known manner. For example, a portion of the water pumped by the jet propulsion unit **34** may be delivered to the engine cooling jacket. This water is then circulated through the engine, and either part of it is discharged to the cooling jacket **64** through a conduit **65** and inlet port **66** or this water may be delivered directly from the pump.

The outlet end of the C-shaped pipe section **57** is connected by a further elastic coupling **67** to a combined expansion chamber and catalytic converter device, indicated generally by the reference numeral **68**. This device **68** is comprised of an inner shell **69** which defines an expansion chamber volume **71**. This is connected by the coupling **67** to the inner pipe section **59** so as to receive the exhaust gases therefrom. An outer shell **72** is connected to the inner shell **69** by a header **73** and defines a cooling jacket **74** therearound. Water from the cooling jacket **64** of the C-shaped pipe section **57** is delivered to this cooling jacket **74**.

In accordance with a feature of the invention, a catalyst bed, indicated generally by the reference numeral **75**, is sandwiched in the expansion chamber **71** between the inner shell **69** and a further downstream inner shell **76**. The catalyst bed **75** is comprised of an annular shell **77** that, in turn, receives a honeycomb-type catalyst bed **78** of a suitable catalytic material. The bed **78** may, for example, be designed primarily to treat hydrocarbons such as oil in the exhaust and render them harmless. An outer flange **79** supports the shell **77** and is maintained between the outer shell **72** and a further outer shell **81** that surrounds the inner pipe section **78**. This inner pipe section **78** has a flange portion **82**, with the flange **79** of the catalyst bed being maintained between the shell portions **69**, **72**, **76**, and **78** by threaded fasteners **83**.

The shells **76** and **81** define a further water jacket **84** that receives coolant from the cooling jacket **74** through a plurality of passages **85** formed in the catalyst bed flange portion **79**.

From this construction it should be readily apparent that the catalyst bed **75** will pass all of the exhaust gases from the engine, and it will be maintained at a desired temperature. However, the cooling jackets **64**, **74**, and **84** will preclude the transmission of heat from the catalyst bed **75** and the exhaust gases from the remainder of the engine compartments.

It should be noted that the catalyst bed **75**, and specifically the actual bed portion **78**, is disposed above the water level line L_w, which is shown in FIG. **1**, under all conditions of the watercraft. The line L_w indicates the water level when traveling at low speed or being stationary. Thus, the catalyst bed **75** will be protected from water contamination by virtue of its height above the water level under all normal conditions of the watercraft **21**.

The inner shell **78** is provided with a downwardly turned portion **86** that has a discharge opening **87**, which in turn communicates with a flexible pipe section **88** so as to define a continuing water path **89** around this area. The section **88** terminates short of a corresponding part **91** of the outer shell **81** which is received within a flexible conduit **92**. Hence, at this point and downstream of the catalyst bed **78** the cooling water from the cooling jackets will be introduced into the exhaust system.

Referring now primarily to FIGS. **1** and **2**, the flexible conduit **92** extends rearwardly along one side of the aforenoted tunnel which appears partially in FIG. **2** and which is identified by the reference numeral **93**. This conduit **92** is connected to the inlet section of a water trap device **94** that is disposed within the hull on one side of the tunnel **93**, and particularly on one side of the jet propulsion unit **34**. As is well known in this art, the water trap device **94** is sized so as to provide a sufficient volume to retain water and preclude it from flowing into the engine. In addition, internal baffles may be provided so as to provide water separation functions to offer still further water control.

An exhaust pipe **95** exits from the water trap device **94** and extends upwardly across the top of the tunnel **93** to a discharge end **96** that opens into the tunnel at an area that is close to or actually below the water level L_w.

In order to provide atmospheric air for the operation of the engine **38** and also to provide ventilation for the engine compartment and cooling of the exhaust system and catalyst bed **75**, there is provided a ventilation system, which is shown in most detail in FIGS. **1** and **2**. This ventilating system includes an atmospheric air inlet opening **97** which is provided in a concealed area under the deck **24** and which may be formed at the end of a water trap device that precludes wager from being drawn into the engine compartment. The ventilating air inlet **97** is directed generally downwardly at the front of the fuel tank **51** so that air will be introduced into this area and flow rearwardly.

A discharge conduit **98** is provided at the rear portion of the engine compartment and has a forwardly facing opening **99** so that the air will flow through it and then be extracted to an area beneath the seat cushion **27**. Hence, there will be a good flow of cooling and ventilating air, and this air flow

will actually pass across the outer periphery of the exhaust system and the catalyst bed **75** so as to effectively cool it and offer further protection.

FIGS. **6–10** show another embodiment of the invention which is generally similar to the embodiment of FIG. **1**. For that reason, numerous components of this embodiment have been identified by the same reference numerals as those applied in the previous description. Where those components are the same as those previously described, they will not be described again, except insofar as may be necessary to understand the construction and operation of this embodiment.

In this embodiment further details of the water trap device **94** are illustrated and will be described first. As has been previously noted, the water trap device **94** is designed so as to provide separation of the water from the exhaust gases and prevent reverse flow. As also has been noted, this is accomplished primarily by baffles in the water trap device **94** and by its internal volume. Two of these baffles appear in FIG. **6**, and they are identified by the reference numeral **101**. These basically comprise dividing walls within the interior of the water trap device **94** and which have nonaligned openings therein.

Referring now in more detail to the differences between this embodiment and that previously described, these deal with the location of the catalyst bed and its protection from water. In addition, this embodiment provides an arrangement whereby the catalyst bed may be washed with fresh water after the watercraft is taken out of service, and particularly when it has been operating in a marine environment.

In this embodiment the conduit **92** which connects the expansion chamber device **68** to the water trap device **94** is divided into a first conduit section **102** that extends forwardly from the bulkhead **33** and which communicates with the expansion chamber device **68** at its inlet end.

The outlet end of the first flexible conduit section **101** is received on the tubular outer shell **77** of the catalytic bed, indicated generally by the reference numeral **103** in this embodiment. The outlet end of this shell is connected to a further flexible conduit **104** which, in turn, delivers the exhaust gases to the water trap device **94**. Thus, in this embodiment the catalyst bed **103**, in addition to being positioned on the opposite side of the engine and specifically a vertical plane V at the forward end of the engine from the fuel tank **51**, is more widely spaced from it.

This embodiment also shows that the catalytic device **103** may be positioned beneath a storage compartment **105** which is, in turn, disposed beneath the seat **27** and a removable rear section **106** thereof. This storage box **105** may be used for storage purposes, but in accordance with a feature of the invention, has a lower wall **107** that is pivotal so as to access the catalytic bed **103** for servicing and replacement. In addition, a flushing nozzle **108** is mounted on the outer shell **77**, and a hose can be connected to this flushing section **108** through the aforenoted access path so as to introduce fresh water once the watercraft has been taken out of service and the catalytic bed **103** has cooled sufficiently. In this way the catalytic bed can be flushed with clear water, particularly after operation in a marine environment, so as to remove salt or other deposits which could foul the catalyst bed **103**.

In addition to this distinction, still further protection is provided by the way in which the cooling water is returned to the exhaust gases, and this is shown best in FIGS. **9** and **10**. Unlike the previous embodiment, the lower or downstream end of the cooling jacket **84** is closed, except for a

drain nozzle **109** that is provided therein. A flexible conduit **111** connects this drain nozzle **109** to the water trap device **94** and at a position downstream of at least one of the baffles therein. Hence, water will be returned to the exhaust system well downstream of the catalyst bed **103**, and further protection from contamination or damage is ensured.

Although FIGS. **6–10** show the catalyst bed **103** mounted in the bulk head **33**, it also can be mounted forwardly within the expansion chamber device **68**, either in the location as shown in FIG. **4**, in a forward location therefrom, as shown in phantom lines and wherein the catalyst bed is indicated by the reference numeral **75**, or at the juncture between the C-pipe section **57** and the expansion chamber device **68**, as also shown by the phantom-line view **75*b*** in FIG. **9**.

FIG. **11** shows another embodiment of the invention which is similar to the embodiment of FIGS. **6–10**, but wherein the catalyst bed, indicated generally by the reference numeral **151**, is positioned still further aft of the engine **38**. In this embodiment the catalyst bed **151** is positioned in the inlet section of the water trap device **94**. Thus, a flushing nozzle **152** may be provided forwardly of it, but still beneath the storage box **105**, and specifically its pivoted lower wall **107** for water flushing after the catalyst bed **151** has cooled and after the watercraft has been operating in a hostile environment such as a marine environment.

A watercraft constructed in accordance with a further embodiment of the invention is illustrated in FIG. **12** and is indicated generally by the reference numeral **201**. This watercraft differs from that previously described in that the hull **202** is configured so as to accommodate primarily only a single rider seated in straddle fashion on a rearwardly positioned seat **203**.

Like the previously described embodiments, foot areas (not shown) are defined on opposite sides of the seat **203**, and the foot areas open to the rear of the transom. In this embodiment an engine, which may have the same construction as those previously described, and thus is identified by the reference numeral **38**, is disposed beneath an access panel **204** formed forwardly of the seat **203** but still in the rider's area. Hence, in this embodiment the engine **38** is not disposed beneath the seat, but still is disposed in the same general area, rearwardly of a fuel tank **51**.

In this embodiment a slightly different control mast is employed, and this is identified by the reference numeral **205**. The control mast **205** is connected to the steering nozzle for steering movement and also may provide other controls for the propulsion unit.

This embodiment shows the engine exhaust ports, and they are indicated generally by the reference numeral **206**, and this may be the same construction as shown in the previously described embodiment which has not been illustrated there. That is, the illustration of the ports **206** in this figure may be considered the illustration of the exhaust ports of the engine in the previously described embodiments.

In this embodiment an exhaust manifold **207** collects the exhaust gases from the ports **206**. However, they are delivered to an exhaust system, indicated generally by the reference numeral **208**, in an upward direction. The exhaust system **208** is comprised of an inner pipe **209** that communicates with the exhaust passages of the manifold **207** and an outer pipe **211** that defines a cooling jacket **212** therebetween. Water may be delivered to this cooling jacket from the engine through the cooling jacket of the exhaust manifold **207** in a known manner.

It will be seen that the exhaust system **208** curves upwardly, forwardly, and then downwardly to a horizontally

disposed expansion chamber section **213**. A catalyst bed **214** is positioned in the discharge from this section **213** and which extends into the interior of the water trap device **94** which may have a construction as previously described.

The cooling jacket of the horizontal section **213** of the exhaust conduit **208** has a water discharge nipple **109** as previously described that communicates with a flexible conduit **111** for delivery of the cooling water to the water trap device **95**, but rearwardly of its forwardmost baffle **101** so as to protect the catalyst bed **214**.

Alternatively, the catalyst bed **214** may be positioned in the interior of the expansion chamber section **213**, as shown by the phantom-line showing **214***a*.

In this embodiment the exhaust pipe **95** discharges rearwardly through the fransom rather than into the tunnel. This arrangement may be utilized with the previous embodiment or vice versa. This embodiment also does not illustrate the ventilation system, but it may be of the type previously described so that the flow of ventilating air will pass across the catalyst bed **214**.

FIG. **13** shows another embodiment of the invention which is generally the same as the embodiment of FIG. **12**, except for the position of the catalyst and the way the cooling water is returned to the exhaust system. For that reason, where components of this embodiment are the same as those of FIG. **12** or earlier embodiments, they are identified by the same reference numerals and will not be described again, except insofar as is necessary to understand the construction and operation of this embodiment.

In this embodiment a U-shaped pipe section, indicated generally by the reference numeral **231**, receives the exhaust gases from the exhaust manifold **207**. This includes an outer pipe portion **232** and an inner pipe section **233**. It should be noted that the inner pipe section **233**, which actually receives the exhaust gases, terminates at a discharge end **234** which is spaced from the outer section **232** so as to define an area **235**. Cooling water contained within the cooling jacket **236** formed between the inner and outer sections **232** and **233** mixes with the exhaust gases in the area **235**.

A catalyst bed **237** is positioned at the inlet of the pipe section **233**, and thus is protected from the water by the trap-like effect of the U-shape of the pipes **233** and **236**.

A flexible conduit **238** interconnects the outer end of the outer pipe **232** with the expansion chamber device **213**, and in all other regards this embodiment is like those previously described. It should be noted that in this embodiment the catalyst bed **237** is positioned on the opposite side of the vertical plane V containing the front of the engine from the fuel tank **51** so as to provide the aforenoted heat protection.

FIG. **14** is a view of another embodiment which is similar to the embodiment of FIG. **13**. However, in this embodiment the water trap device, indicated generally by the reference numeral **271**, is positioned to the front of the fuel tank **59**. Hence, the orientation of the U-shaped pipe section **232–233** is reversed, and the expansion chamber device **213** extends forwardly rather than rearwardly.

In this embodiment an exhaust pipe **272** discharges the exhaust gases from the water trap device **271** to the atmosphere through the side of the hull **202**. In addition, a further water trap device **273** is interposed between the expansion chamber device **213** and the water trap device **271**, which has a double trap section, as shown in phantom lines.

In many of the embodiments described, the catalytic bed is disposed at a relatively high level so that it will be above the water level when the watercraft with which it is associated is in the normal position in the water, yet either at cruise or under idle conditions. Next will be described an embodiment wherein some of the advantages previously described are enjoyed and, furthermore, wherein the catalytic bed is positioned so that regardless of how the watercraft may be in the water, whether erect, inverted, partially or fully capsized, it will be above the water level.

This embodiment is shown in FIGS. **15–18**, and the watercraft generally has the same configuration of that of FIGS. **1–5**. For that reason, components which are the same including those of the basic watercraft, have been identified by the same reference numerals and will be described again only insofar as is necessary to understand the construction and operation of this embodiment.

It should be noted that the watercraft constructed in accordance with this embodiment, which is indicated generally by the reference numeral **301**, has an exterior configuration that is similar to but not identical to that of the embodiment of FIGS. **1–6**. However, the general layout of the components is the same, and for that reason they have been identified by the same reference numerals where they function to provide the same general purpose. This, however, further points out how the invention is not limited to the particular external shape of the watercraft, even though it has certain advantages in conjunction with the configurations which have been described.

In this embodiment the engine exhaust manifold **56** has a rearwardly facing discharge opening. This communicates with a reverse C-shaped section **302** that conveys the exhaust gases upwardly and forms a portion of an exhaust system, indicated generally by the reference numeral **303**. This exhaust system **303** includes an expansion chamber device **304** that is disposed at a relatively high location in the hull and along one side of the engine. At its forward end the expansion chamber device **303** has a downwardly facing outlet fitting **305** to which a catalytic converter assembly, indicated generally by the reference numeral **306**, is connected by means of a first flexible conduit **307**. The conduit **307** delivers the exhaust gases to a horizontally disposed, transversely extending catalyst bed **308** which may be of any known type, depending upon the treatment which it is intended to provide. A further flexible conduit **309** extends from the discharge end of the catalyst **308** to a water trap device **311** which is disposed on the side of the engine **38** opposite the expansion chamber device **303**. Hence, the side-to-side balance of the watercraft is maintained with this arrangement.

The exhaust pipe **95** extends from the water trap device **311** along one side of the jet propulsion unit **34** to the discharge opening **96** in the tunnel, as aforedescribed.

Since the catalyst **308** is positioned to the front of the watercraft **301**, a saddle-type fuel tank **312** is provided in the area beneath the seat **27** and foot areas and which supplies fuel to the engine. Hence, the positions of the catalyst bed **308** and fuel tank **312** are reverse from most of the embodiments previously described. In any event, however, there is obtained maximum spacing between these components so that there will be no heat transfer therebetween.

In addition, it should be noted that the vent pipe **97** that admits the ventilating air to the engine compartment in this embodiment is extended, as at **313**, so as to deliver the ventilating air at a low area so that it can flow rearwardly as shown by the phantom arrow **314** to flow across the catalyst bed **308** and cool it. Hence, this embodiment also provides good cooling for the catalyst and ensures that the heat from it will not contact or heat other critical elements of the system.

As seen in FIG. **18**, the catalyst bed **308** is comprised of the bed portion itself, indicated generally by the reference numeral **314**, that has a tubular outer shell **315** to which the flexible conduits **307** and **309** are connected by a slip fit.

Referring now to FIG. **17**, it will be described how the catalyst bed **308** is positioned so that it will be protected from contact with water, regardless of what orientation the watercraft **301** may be forced into. In the position of the normal watercraft operation when planing or when operating at a relatively low speed, the catalyst bed **308** is disposed above the water level WL_n, as clearly shown in this figure. Also, if the watercraft is inverted so that the water level is in the condition WL_i, it will be seen that the bed **308** is again above the water level.

If the watercraft is forced over on one side and held in this condition, as shown in the phantom line WL_{s-1}, the bed **308** will be above the water level. In a like manner, if tilted over onto the other side, as shown at WL_{s-2}, the bed **308** is still above the water level.

If the water level is in intermediate positions from either side, as shown by the remaining lines WL_{pi}, in any condition, the catalyst bed is still protected. Therefore, this embodiment is very effective in ensuring that regardless of what attitude the watercraft is in, water can never reach the catalyst bed because it will always be above the water level.

From the foregoing description it should be readily apparent that the preferred embodiments of the invention as described are very effective in providing good catalytic exhaust treatment for a small watercraft such as a personal watercraft and protection, regardless of what extreme conditions may be encountered. In addition and in spite of the small physical nature of these watercraft, the heat from the converter is maintained away from critical components such as the fuel tank. In addition, some embodiments permit flushing of the converter easily so as to clear it of salt water, and in all embodiments water protection is provided in a variety of manners under a variety of conditions. Of course, the foregoing description is that of preferred embodiments of the invention, and various changes and modifications may be made without departing from the spirit and scope of the invention, as defined by the appended claims.

We claim:

1. A personal watercraft having a hull defining a rider's area sized to accommodate at least one rider, said hull defining an engine compartment containing an internal combustion engine having at least one exhaust port and an output shaft, a propulsion device carried by said hull and driven by said engine output shaft for propelling said watercraft, an exhaust system for conveying exhaust gases from said engine exhaust port to the atmosphere, and a catalyst in said exhaust system for treating the exhaust gases before discharge to the atmosphere, said catalyst being position within said hull so as to be above the water surface level of the body of water in which the watercraft is operated with the hull floating in a normal upright position and in an inverted position.

2. A personal watercraft as set forth in claim **1**, wherein said catalyst is positioned so that it will be above the water surface level with the watercraft floating on its side.

3. A personal watercraft as set forth in claim **1**, wherein said catalyst is positioned so that it will be above the water surface level with the watercraft floating in an intermediate position between a normal upright position and a position with the hull lying on its side.

4. A personal watercraft as set forth in claim **1**, wherein said catalyst is positioned so that it will be above the water surface level with the watercraft floating in an intermediate position between the inverted position and a position with the hull lying on its side.

5. A personal watercraft having a hull defining a rider's area sized to accommodate at least one rider, said hull defining an engine compartment containing an internal combustion engine having at least one exhaust port and an output shaft, a propulsion device carried by the hull and driven by the output shaft for propelling the watercraft, and an exhaust system for conveying exhaust gases from said engine to the atmosphere, said exhaust system comprising a catalyzer positioned within an exhaust conduit, a coolant jacket extending along a portion of the exhaust conduit, said catalyzer including a catalyst bed supported by a flange within said conduit, said flange being interposed between first and second conduit sections of said conduit and including at least one passage to permit coolant to flow through said flange from a first segment of the cooling jacket juxtaposing the first conduit section to a second segment of the cooling jacket juxtaposing the second conduit section.

6. A personal watercraft as in claim **5**, wherein said catalyst bed is supported at a positioned within said conduit away from an inner wall of said conduit.

7. A personal watercraft as in claim **5**, wherein said conduit comprises an expansion chamber at least partially surrounded by said coolant jacket, said expansion chamber and said coolant jacket being formed by the first and second conduit sections of the conduit, each conduit section having a double-walled shell construction with the corresponding segment of the cooling jacket being formed between shell walls of the conduit section, said catalyst bed being positioned within said expansion chamber.

8. A personal watercraft as in claim **7**, wherein said flange includes a plurality of apertures which communicate with the coolant jackets of said first and second conduit sections, said apertures being located on said flange about the catalyst bed.

9. A personal watercraft as in claim **8**, wherein said flange supports said catalyst bed within said expansion chamber at a location spaced from an inner wall of said double-walled conduit sections.

10. A personal watercraft having a hull defining a rider's area sized to accommodate at least one rider, said hull defining an engine compartment containing an internal combustion engine having at least one exhaust port and an output shaft, a propulsion device carried by said hull and driven by said engine output shaft for propelling said watercraft, and an exhaust system for conveying exhaust gases from said engine exhaust port to the atmosphere, said exhaust system comprising first and second exhaust pipes interconnected by a flexible pipe section, said first exhaust pipe connected to the engine exhaust port and the second exhaust pipe supporting a catalyzer.

11. A personal watercraft as in claim **10**, wherein said hull defines an access opening near said catalyzer.

12. A personal watercraft as in claim **11**, wherein a seat cover covers said access opening.

13. A personal watercraft as in claim **10**, wherein said hull has a longitudinal axis and said catalyzer is disposed within said second exhaust pipe which extends in a direction generally transverse to said longitudinal axis.

14. A personal watercraft as in claim **13**, wherein said catalyzer lies near said longitudinal axis of said hull.

15. A personal watercraft having a hull defining a rider's area sized to accommodate at least one rider, said hull having a longitudinal axis and defining an engine compartment containing an internal combustion engine having at least one exhaust port and an output shaft, a propulsion

device carried by said hull and driven by said engine output shaft for propelling said watercraft, an exhaust system for conveying exhaust gases from said engine exhaust port to the atmosphere, and a catalyzer positioned within an exhaust pipe of said exhaust system which extends generally transverse to said longitudinal axis of said hull.

16. A personal watercraft as in claim **15**, wherein said catalyzer lies near said longitudinal axis of said hull.

17. A personal watercraft as in claim **15**, wherein said exhaust pipe, in which said catalyzer is positioned, is connected to another exhaust pipe by a flexible conduit, said another exhaust pipe being attached to said engine.

18. A personal watercraft having a hull defining a rider's area sized to accommodate. at least one rider, said hull having a longitudinal axis and defining an engine compartment containing an internal combustion engine having at least one exhaust port and an output shaft, an induction system for the engine, the induction system having an air inlet, a propulsion device carried by said hull and driven by said engine output shaft for propelling said watercraft, an

exhaust system for conveying exhaust gases from said engine exhaust port to the atmosphere, a catalyzer in said exhaust system for treating the exhaust gases before discharge to the atmosphere, and at least first and second air ducts, said ducts and said induction system air inlet aligned along a common line with said induction system air inlet positioned between said first and second ducts, said catalyzer being positioned near said induction system air inlet.

19. A personal watercraft as set forth in claim **18**, wherein said air ducts each have a port which lies within the engine compartment at a vertical position at least as high as the vertical position of a portion of the catalyzer.

20. A personal watercraft as set forth in claim **18**, wherein the catalyzer lies at a vertical position at least as high as the level of the inlet of the induction system.

21. A personal watercraft as set forth in claim **18**, additionally comprising a fuel tank positioned in front of said engine.

* * * * *

Exhibit 10

US005967063A

United States Patent [19]

Wu

[11] **Patent Number: 5,967,063**

[45] **Date of Patent: Oct. 19, 1999**

[54] **SEA-GOING VESSEL WITH A SOLID-WASTE INCINERATOR**

[76] Inventor: **Yi-Jun Wu**, No. 133, Erh-Sheng-Erh Rd., Chien-Chen Dist., Kaohsiung City, Taiwan

[21] Appl. No.: **09/074,841**

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[51] **Int. Cl.**[6] **F23G 5/00**; F23G 5/40; B63B 17/06

[52] **U.S. Cl.** **110/240**; 110/210; 110/215; 110/259; 114/26; 114/73; 114/187; 114/270

[58] **Field of Search** .... 110/240, 203, 110/208, 210, 211, 215, 216, 233, 234, 235, 238, 241, 255, 259, 293, 295, 346, 104 R, 349; 114/26, 72, 73, 74 R, 187, 270

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,046,112	6/1936	Felton, Jr.	110/240
2,244,024	6/1941	Schadek	110/240
2,442,686	6/1948	Guerchoux	110/240 X
3,663,149	5/1972	Heagler .	
4,552,082	11/1985	Grey	114/26
5,067,425	11/1991	Sporleder	114/26
5,324,217	6/1994	Mineo	114/270 X

FOREIGN PATENT DOCUMENTS

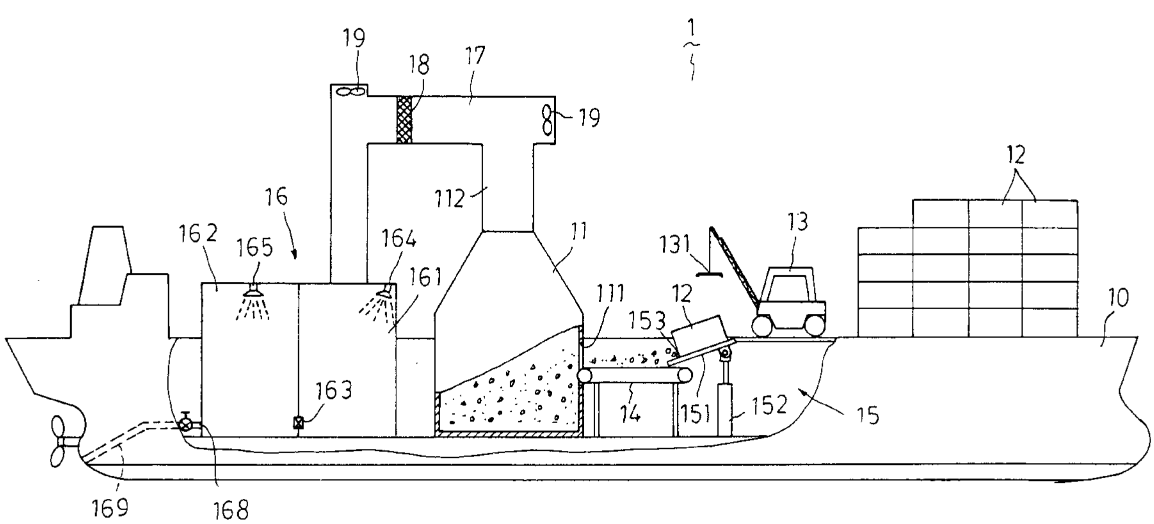
3-110313	5/1991	Japan	110/240
575 101	4/1976	Switzerland	110/240

Primary Examiner—Ira S. Lazarus
Assistant Examiner—Ljiljana V. Ciric
Attorney, Agent, or Firm—Ladas & Parry

[57] **ABSTRACT**

A waste-disposing sea-going vessel includes a vessel body that carries solid waste-holding containers to a site at sea far away from land. The vessel body further has an incinerator to incinerate the solid wastes of the containers, a scrubbing chamber to scrub the smoke produced by the incinerator via sea-water, and a neutralization chamber to spray an alkaline solution onto the products produced by the scrubbing chamber, thereby removing hazardous particles before the incinerated wastes are discharged into the sea. A smoke-conveying pipe is further provided to connect a chimney of the incinerator to the scrubbing chamber, and a catalyst converter is provided in the smoke conveying pipe to remove some hazardous smoke particles by filtration and chemical conversion before the post-treatments conducted by the scrubbing chamber and the neutralization chamber.

8 Claims, 3 Drawing Sheets



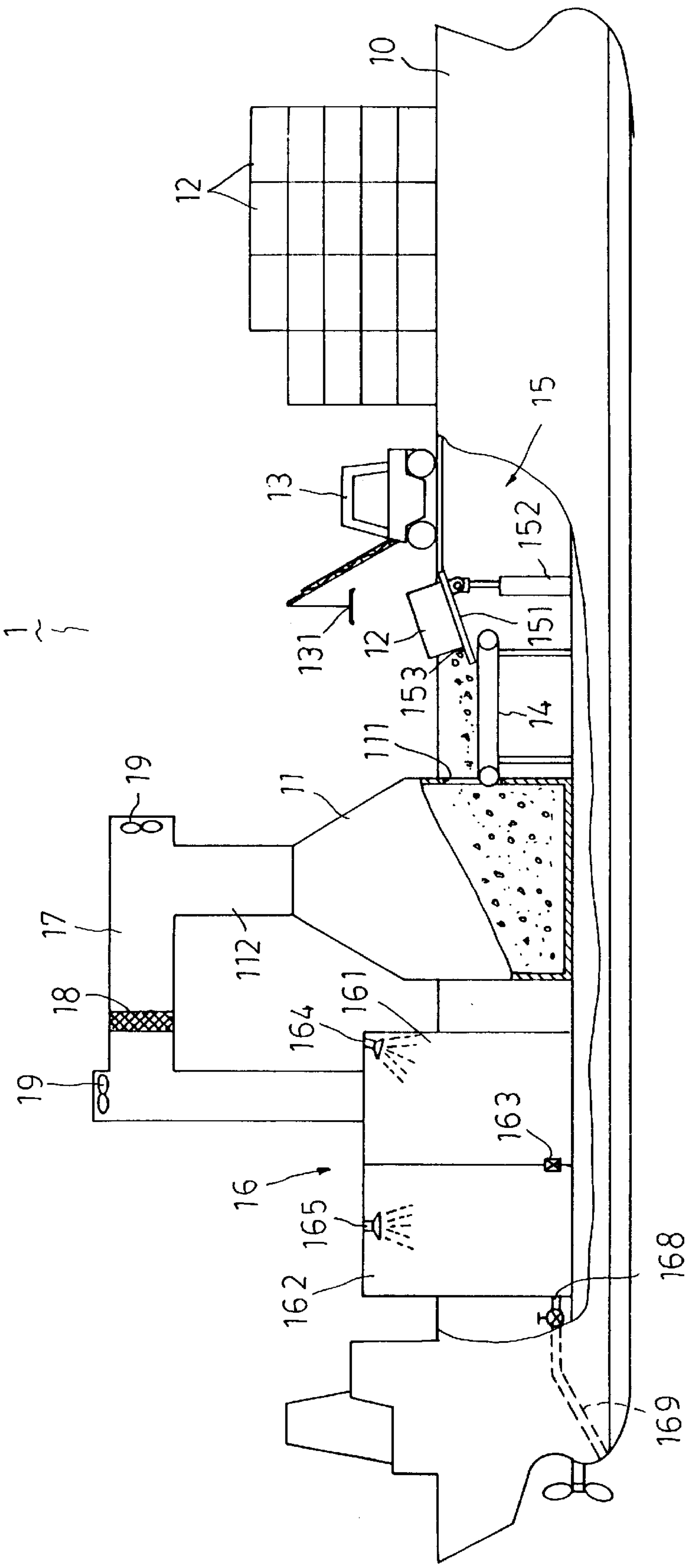

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FIG. 1

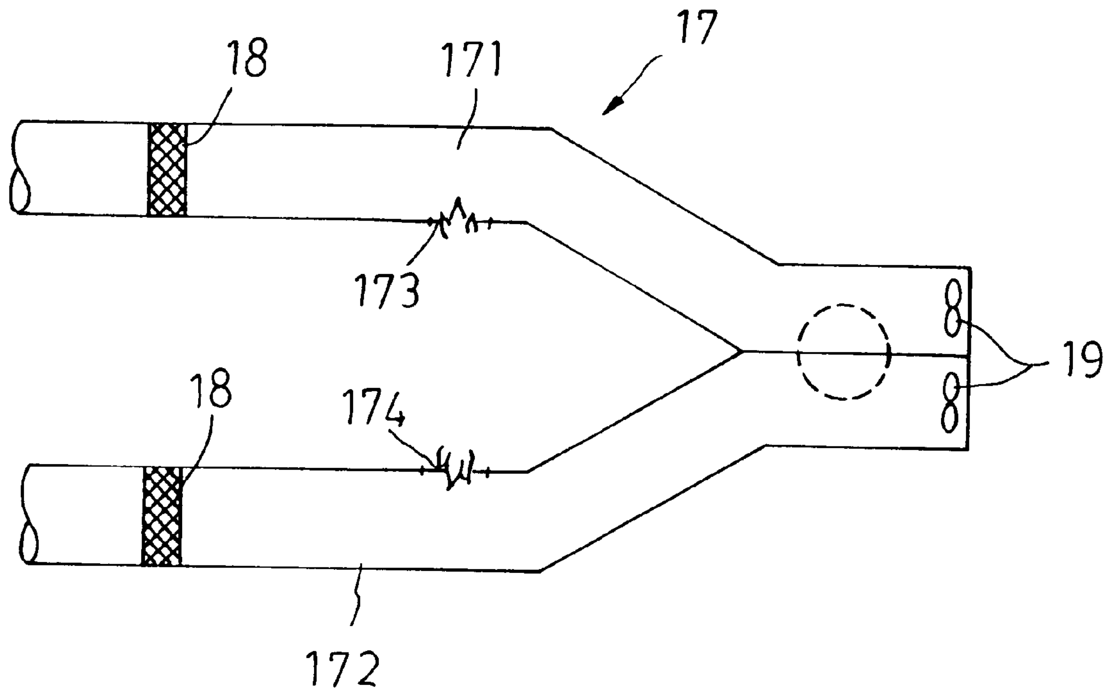

FIG. 2

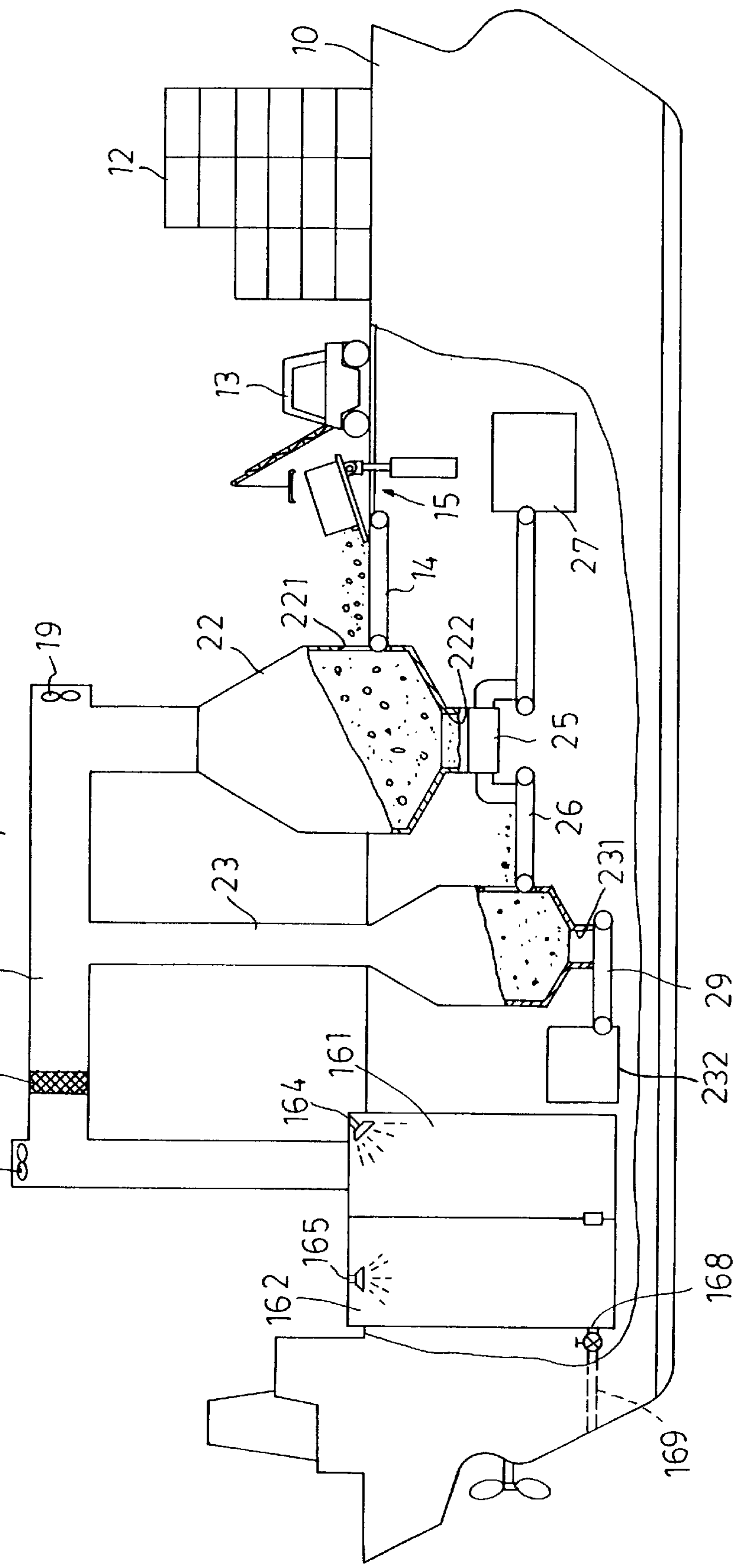
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FIG. 3

SEA-GOING VESSEL WITH A SOLID-WASTE INCINERATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a sea-going vessel for disposing wastes, more particularly to a sea-going vessel which is provided with a solid-waste incinerator and enclosed chambers for post-treatment of the products of incineration so as to remove hazardous substances therefrom.

2. Brief Description of the Related Art

Disposal of industrial and medical wastes by dumping into the sea or disposal sites on land is not safe for they contain hazardous chemicals and infectious viruses which will pollute underground water resources and the sea and which will endanger to biological systems. Although such hazardous wastes can be eliminated by incineration, incinerators installed on land have caused serious air pollution problems, such as the acidifying of the atmosphere to produce acid rain, the production of holes in the ozone layer, etc., which are harmful to living things. On the other hand, sites for incineration available on land have become limited due to the increasing population. People tend to deny the use of their environment as disposal sites. In order to provide an efficient solution to the problem of disposing such dangerous wastes, incineration of wastes far away from land is desirable.

SUMMARY OF THE INVENTION

An object of the invention is to provide a solid waste disposing sea-going vessel to incinerate dangerous wastes at sea far away from land.

Another object of the invention is to provide a seagoing vessel with an incinerator and enclosed chambers for post-treatment of the products of incineration, thereby effectively eliminating harmful substances before the incinerated wastes are discharged into sea.

According to the present invention, a waste-disposing sea-going vessel comprises: a vessel body; at least one incinerator mounted on the vessel body and having a waste inlet and a chimney; a plurality of containers disposed on the vessel body to receive solid wastes; delivery means for delivering the solid wastes from the containers to the waste inlet; a scrubbing chamber having a first spraying unit to spray sea-water onto the smoke directed to the scrubbing chamber from the chimney; a smoke-conveying pipe connected to the chimney and the scrubbing chamber so as to direct the smoke from the chimney to the scrubbing chamber; a neutralization chamber connected to the scrubbing chamber and having a second spraying unit to spray an alkaline solution onto the products of scrubbing which enter the neutralization chamber from the scrubbing chamber; and means for discharging the products resulting from the neutralization chamber into the sea.

Preferably, the delivery means comprises a belt conveyor provided at the waste inlet to receive the solid wastes from the containers and to feed the same into the incinerator; a tilting device having a tilting platform to receive and tilt the containers so as to deliver the solid wastes from the containers to the conveyor belt; and a transporting cart to transport the containers to the tilting platform, the transporting cart having a crane to deliver the containers onto the tilting platform.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the present invention will become apparent in the following detailed description of the preferred embodiments with reference to the accompanying drawings, of which:

FIG. **1** is a schematic view illustrating an embodiment of a waste-disposing sea-going vessel according to the present invention;

FIG. **2** is a schematic view showing a portion of the embodiment of FIG. **1**; and

FIG. **3** is a schematic view of another embodiment of a waste-disposing sea-going vessel according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a sea-going vessel **1** is shown to include a vessel body **10**, an incinerator **11**, a plurality of solid waste containers **12** provided on the deck of the vessel **1**, transporting carts **13** (only one cart is shown) for transporting the waste containers **12** , conveyor belts **14** (only one is shown), tilting devices **15** (only one is shown), a scrubbing chamber **161**, a smoke conveying pipe **17** to intercommunicate a chimney **112** of the incinerator **11** and the scrubbing chamber **16**, and a discharge pipe **169** communicated with a neutralization chamber **162**.

The incinerator **11** is provided with three waste inlet ports **111**. The conveyor belts **14** are provided adjacent the waste inlet ports **111**, respectively, in order to feed the solid wastes from the containers **12** into the incinerator **11**. Each transporting cart **13** has a crane **131** to lift and carry the containers **12** to tilting platforms **151** of the tilting devices **15**. Each tiling platform **151** is operated by a hydraulic lift **152** which is disposed below the tilting platform **151** to perform a tilting operation. A stop member **153** is disposed on each tilting platform **151** in order to stop the containers **12** from sliding downward when the tilting platform **151** is tilted.

The scrubbing chamber **161** has a passage **163** which intercommunicates the scrubbing chamber **161** and the neutralizing chamber **162**. The scrubbing chamber **161** is provided with a first spraying device **164** to spray sea-water onto the smoke directed into the scrubbing chamber **161** from the chimney **112**. The neutralization chamber **162** is provided with a second spraying device **165** to spray an alkaline solution. The discharge pipe **169** is connected to the neutralization chamber **162** via a discharge port **168**.

As shown in FIG. **2**, the smoke conveying pipe **17** includes a bifurcated portion having two branch pipes **171** and **172** which are respectively connected to the scrubbing chamber **161**. The branch pipes **171** and **172** are provided with a secondary burning unit which includes two flame inlet ports **173** and **174**. Catalyst converters **18** are disposed in the branch pipes **171** and **172** downstream of the flame inlet ports **173** and **174**. Exhaust fans **19** are provided in the branch pipes **171** and **172** to fan the smoke of incineration.

In operation, the containers **12**, which are filled with solid wastes on land, are loaded on the vessel **1** so as to incinerate the solid wastes at sea. The transporting carts **13** transport the containers **12** to the tilting platforms **151** where the containers **12** are tilted to deliver the solid wastes onto the conveyor belts **14**. The conveyor belts **14** feeds the solid wastes into the incinerator **11**. The resulting smoke or incineration products flow upward through the chimney **112** of the incinerator **11**. The smoke-conveying pipe **17** directs the smoke which flows upward from the chimney **112** in a downward direction to the scrubbing chamber **161**. The exhaust fans **19** function to accelerate the flowing rate of the smoke. At the flame inlet ports **173** and **174**, ash particles contained in the smoke as a result of incomplete combustion,

are fired again by the flame produced at the flame inlet ports **173** and **174**, thereby reducing large particles to smaller particles and converting hazardous chemical compounds into non-hazardous micro-particles. Downstream from the flame inlet ports **173** and **174**, the catalyst converters **18** remove additional amount of hazardous particles by filtration and chemical conversion. Since the size and the amount of the smoke particles are reduced upstream of the catalyst converters **18**, the service life of the catalyst converters **18** can be prolonged, thereby minimizing the frequency of cleaning operation. With the provision of the catalyst converters **18**, the load to be borne at the post-treatment stages can be minimized, and the efficiency of the post-treatment can be increased.

When the smoke is directed into the scrubbing chamber **161**, the first spraying device **164** sprays sea-water, which contains basic substances, onto the smoke, thereby cooling the smoke and combining the smoke with the sea-water. The products of the scrubbing are led to the neutralization chamber **162** in which an alkaline solution is sprayed by the second spraying device **165** to remove additional hazardous substances. Finally, the products resulting from neutralization are discharged into the sea via the discharge port **168** and the discharge pipe **169**.

Of numerous kinds of incinerators, any suitable incinerator may be selected for use in the present invention. The incinerator may be a tunnel-type incinerator, a twin-incinerator, or a single incinerator. FIG. **3** shows another embodiment of the present invention, wherein elements similar to those employed in the previous embodiment are represented by like numerals. Except for the use of a twin-incinerator, this embodiment is substantially similar to the previous embodiment. In particular, this embodiment comprises a vessel body **10** and a twin-incinerator **21**. The twin-incinerator **21** has a first incinerator **22**, and a second incinerator **23**. The first incinerator **22** has a waste inlet **221** adjacent to a conveyor belt **14**. The bottom end of the first incinerator **22** is provided with a bottom outlet **222** and an ash-separating device **25**. One side of the bottom outlet **222** is connected to the second incinerator **23** via a conveying belt **26**. The other end of the bottom outlet **222** is connected to an ash collector **27**. A bottom outlet portion **231** of the second incinerator **23** is connected to a waste residue collector **232** via a conveying belt **29**. The top end of the second incinerator **23** is connected to a smoke-conveying pipe **17'** upstream of a catalyst converter **18**.

In operation, containers **12** are tilted by a tilting device **15** to deliver solid wastes onto the conveyor belt **14** which in turn feeds the solid wastes into the first incinerator **22**. After a first incineration at a high temperature of about 500° C., the resulting ash and the products of incomplete combustion are separated by the ash-separating device **25**. The ash is collected in the ash collector **27**. The products of incomplete combustion are sent to the second incinerator **23** via the conveying belt **26** for a second incineration at a super-high temperature, preferably, about 1200° C. The resulting waste residue is discharged from the bottom outlet portion **231** and collected in the waste residue collector **232**. Since the first incinerator **22** has burnt out the wastes, which are combustible at a temperature of lower than 500° C., a reduced amount of wastes are sent to the second incinerator **23** for incineration at a super-high temperature of about 1200° C., thereby saving energy as compared to the previous embodiment which employs a single incinerator that requires high energy to maintain a super-high temperature for all amounts of wastes.

Via the incinerator used in the present invention, the incompletely combusted hydrocarbon compounds can be converted into carbon dioxide. Carbon monoxide and sulfur monoxide can be converted into carbon dioxide and sulfur dioxide. The incompletely combusted oxygenated nitrogen compounds can be decomposed into nitrogen dioxide. Dioxime resulting from the combustion of polymeric compounds can be decomposed into carbon dioxide. In the scrubbing chamber, sulfur dioxide is formed into sulfate salts upon combination with sea-water. Nitrogen dioxide is converted into nitrate salts upon reaction with sea-water. The resulting salts can be further converted into chloride salts upon combination with sea-water. Carbon dioxide produces carbonate salts upon reaction with sea-water. Since the resulting sulfates, nitrates, chlorides and carbonates are stable and non-hazardous compounds in sea water, the wastes, which are finally discharged into the sea after the post-treatment of the smoke produced upon incineration in the present invention, are not harmful to living things and organisms in the sea.

By virtue of the present invention, solid wastes can be incinerated at sea, i.e. far from land, thereby eliminating the air pollution problems encountered with the incinerator installed on land.

With the invention thus explained, it is apparent that various modifications and variations can be made without departing from the spirit of the present invention. It is therefore intended that the invention be limited only as indicated in the pending claims.

What I claim is:

1. A waste-disposing sea-going vessel comprising:

a vessel body;

at least one incinerator mounted on the vessel body and having a waste inlet and a chimney for passage of the smoke produced by said incinerator;

a plurality of containers disposed on said vessel body for receiving solid wastes;

delivery means for delivering the solid wastes from said containers to said waste inlet;

a scrubbing chamber having a first spraying unit to spray sea-water onto the smoke directed to said scrubbing chamber from said chimney;

a smoke-conveying pipe connected to said chimney and said scrubbing chamber so as to direct the smoke from said chimney to said scrubbing chamber;

a neutralization chamber connected to said scrubbing chamber and having a second spraying unit for spraying an alkaline solution onto the substances entering said neutralization chamber from said scrubbing chamber; and

discharge means for discharging the products formed in said neutralization chamber into the sea.

2. A waste-disposing sea-going vessel as claimed in claim **1**, wherein said delivery means includes: a conveyor belt provided at said waste inlet and adapted to receive the solid wastes from said containers and to feed the solid wastes into said incinerator; a tilting device having a tilting platform to receive and tilt said containers so as to deliver the solid wastes from said containers to said conveyor belt, and a transporting cart to transport said containers to said tilting platform, said transporting cart having a crane to deliver said containers onto said tilting platform.

3. A waste-disposing sea-going vessel as claimed in claim **2**, wherein said smoke-conveying pipe is provided with a catalyst converter therein.

4. A waste-disposing sea-going vessel as claimed in claim **3**, wherein said smoke-conveying pipe is further provided with an exhaust fan.

5. A waste-disposing sea-going vessel as claimed in claim **4**, wherein said smoke-conveying pipe further has a secondary burning unit provided upstream of said catalyst converter for burning large particles contained in the smoke directed from said chimney.

6. A waste-disposing sea-going vessel as claimed in claim **1**, which comprises a plurality of said incinerators, said incinerators including a first incinerator and a second incinerator, said second incinerator operating at a temperature higher than that of said first incinerator.

7. A waste-disposing sea-going vessel as claimed in claim **6**, wherein said first incinerator operates at a temperature of about 500° C., while said second incinerator operates at a temperature of about 1200° C., said first incinerator having a bottom outlet, said second incinerator being provided downstream of said first incinerator and having a waste inlet connected to said bottom outlet of said first incinerator for further combusting of the products of incineration of said first incinerator.

8. A waste-disposing sea-going vessel as claimed in claim **7**, wherein said second incinerator has a top end connected to said smoke-conveying pipe, said smoke-conveying pipe containing a catalyst converter downstream of said second incinerator.

* * * * *

Exhibit 11

US006395047B1

(12) **United States Patent**
Smith

(10) **Patent No.: US 6,395,047 B1**
(45) **Date of Patent: May 28, 2002**

(54) **PORTABLE AIRBORNE CONTAMINATION CONTROL SYSTEM INCLUDING A MAIN AND REMOTE UNIT**

(76) Inventor: **William C. Smith**, 10630 S. Riggs Hill Rd., Jessup, MD (US) 20794-9425

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/784,127**

(22) Filed: **Feb. 16, 2001**

(51) **Int. Cl.**[7] **B01D 29/50**; B01D 50/00

(52) **U.S. Cl.** **55/385.2**; 55/385.1; 55/356; 55/DIG. 18; 55/DIG. 46; 454/187

(58) **Field of Search** .... 55/385.1, 385.2, 55/385.6, 356, 471, DIG. 18, DIG. 46; 454/187

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,163,650 A * 8/1979 Watson et al. 55/356
4,512,245 A * 4/1985 Goldman 55/DIG. 18
5,281,246 A * 1/1994 Ray et al. 55/356
5,462,569 A * 10/1995 Benjamin 55/385.6
5,558,112 A * 9/1996 Strieter 55/356
5,593,470 A * 1/1997 Shagott et al. 55/356
5,785,723 A * 7/1998 Beran et al. 55/356
5,853,441 A * 12/1998 Groen et al. 55/356
5,873,919 A * 2/1999 Vross et al. 55/356
5,942,017 A * 8/1999 Van Wrinkle, Jr. 55/385.6
6,022,389 A * 2/2000 Vross et al. 55/356
6,143,048 A * 11/2000 Comproni et al. 55/356

* cited by examiner

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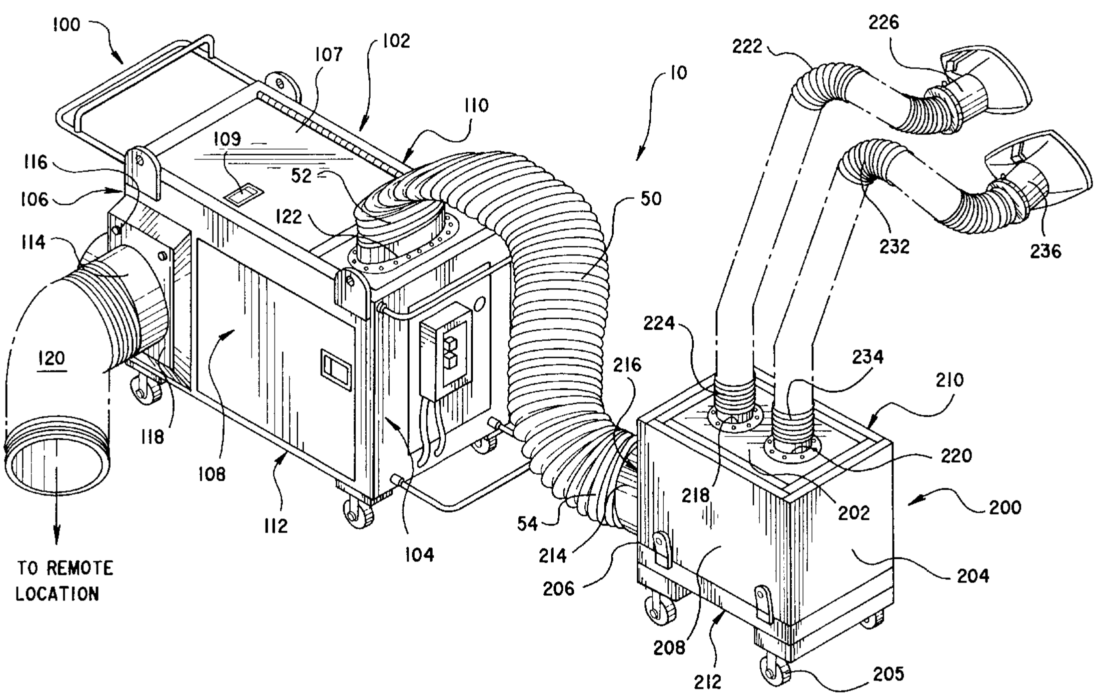
Assistant Examiner—Minh-Chau T. Pham
(74) *Attorney, Agent, or Firm*—Tom Hamill, Jr.

(57) **ABSTRACT**

The invention is an airborne contamination control system with a main device unit and a remote unit. The main airborne contamination control unit is a cabinet including a motor in communication with an air treatment path. The main unit has a variety of configurations enhancing its flexibility. The main unit has the capacity to be connected to a lightweight remote unit. The remote unit is highly portable and of a small dimension which permits it to be employed in areas inaccessible to the main device. The main unit is connected to the remote unit by an elongated and flexible duct. Both the main unit and remote unit have a general cabinet structure with mounting structure designed to receive articulated suction ducts thereon. The articulated suction ducts may be placed proximal a work piece which is being coated, abraded or treated by spraying. The articulated suction ducts collect overspray and errant particles and transports them to and through a filter located in the main unit. The filtered air is then exhausted through an exhaust port on the main unit. An elongated duct may be connected to the exhaust port to transport the air to a distant location. The invention permits the main unit to be employed independently on easily accessible locations as well as in conjunction with the remote unit in difficult to reach locations.

7 Claims, 11 Drawing Sheets



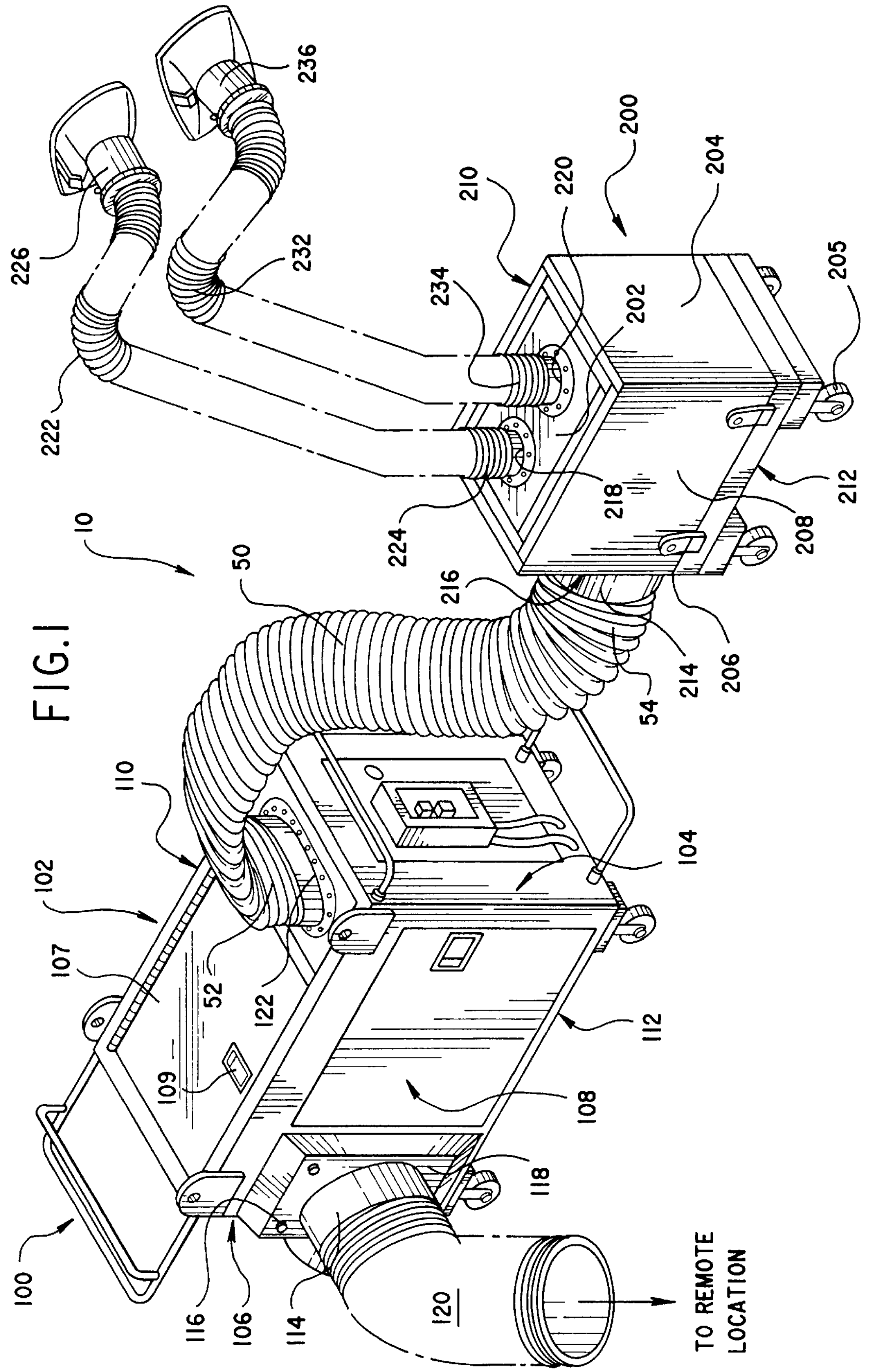


FIG. 1

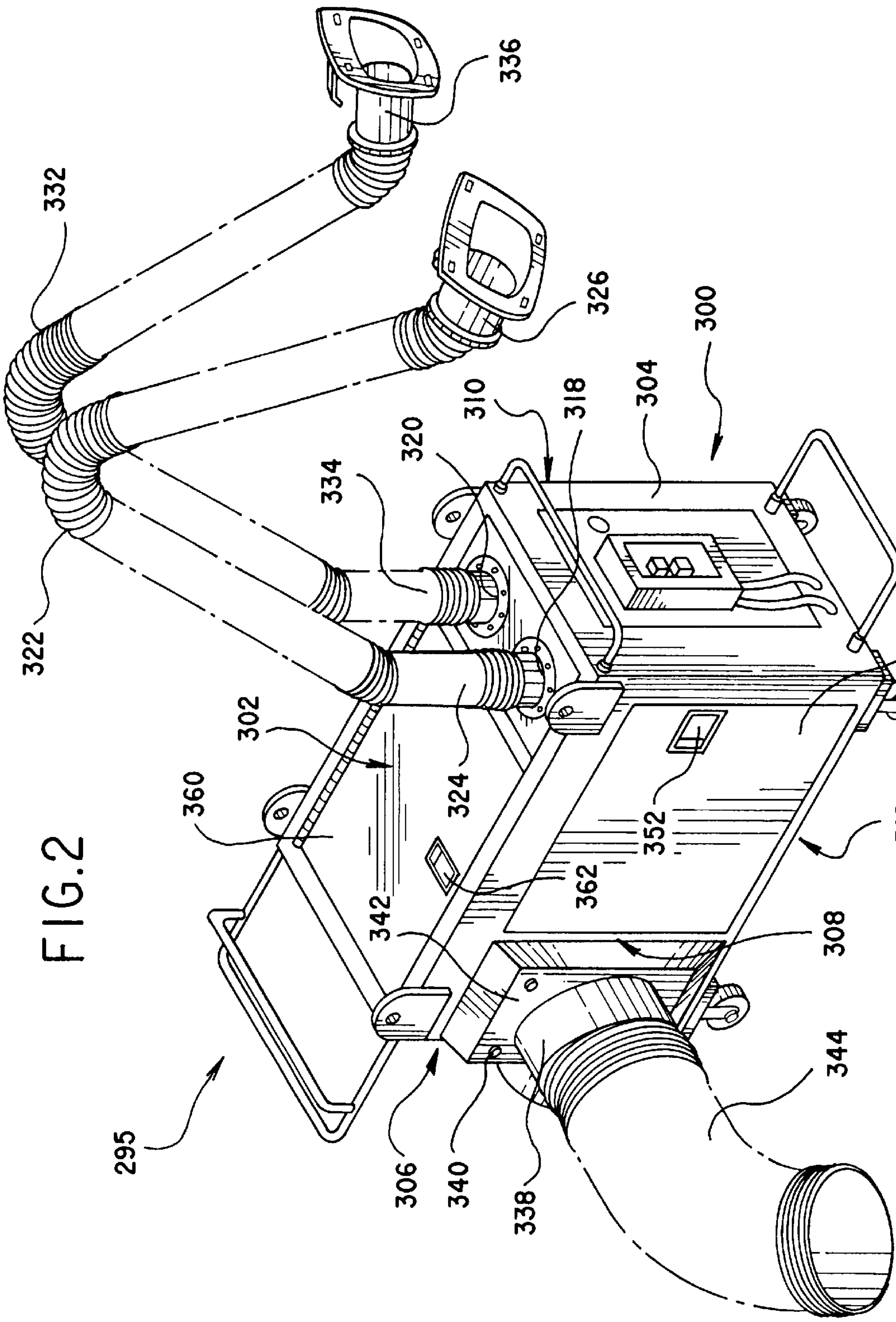

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FIG.2

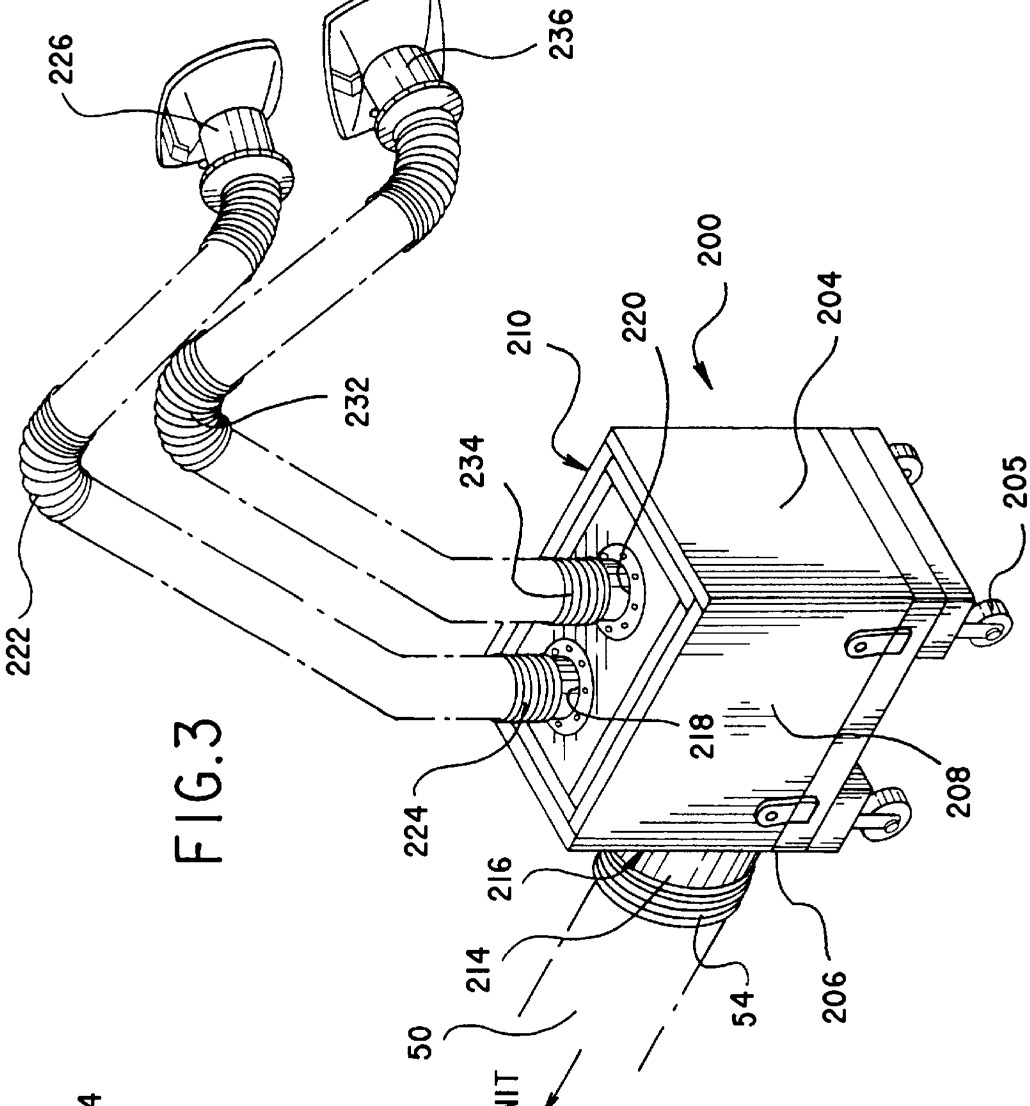


FIG.3

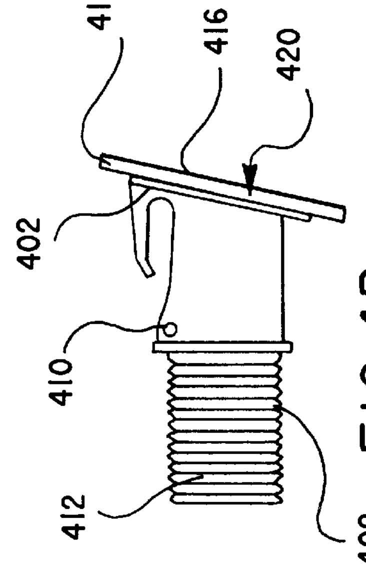


FIG.4B

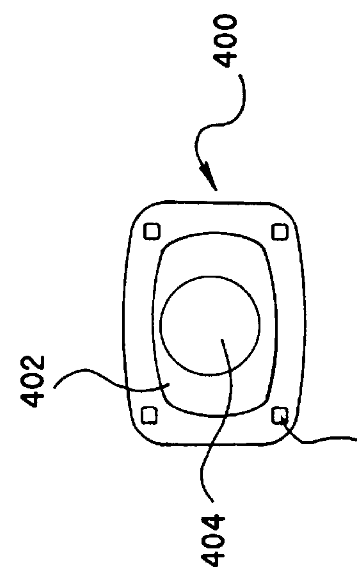


FIG.4A

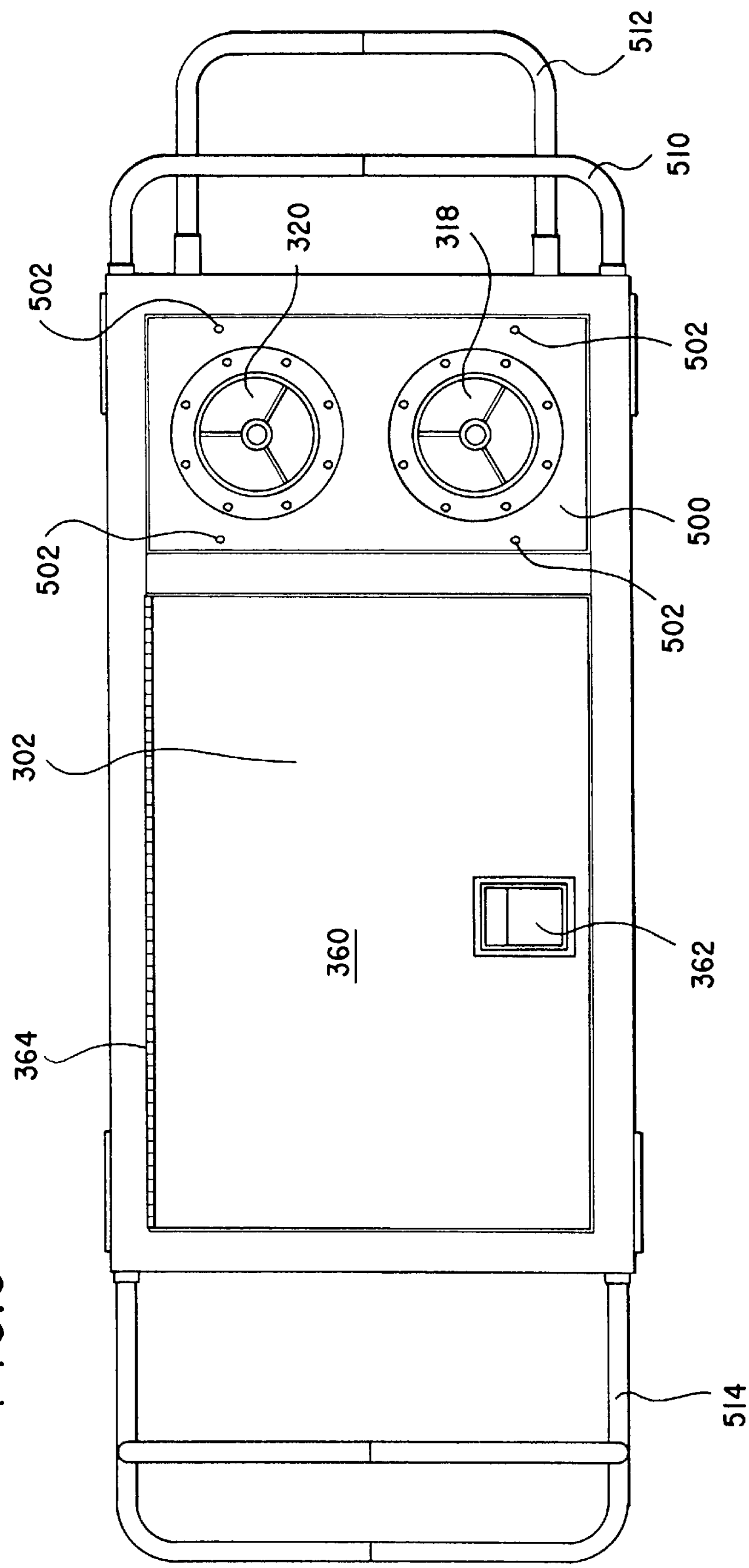


FIG.5

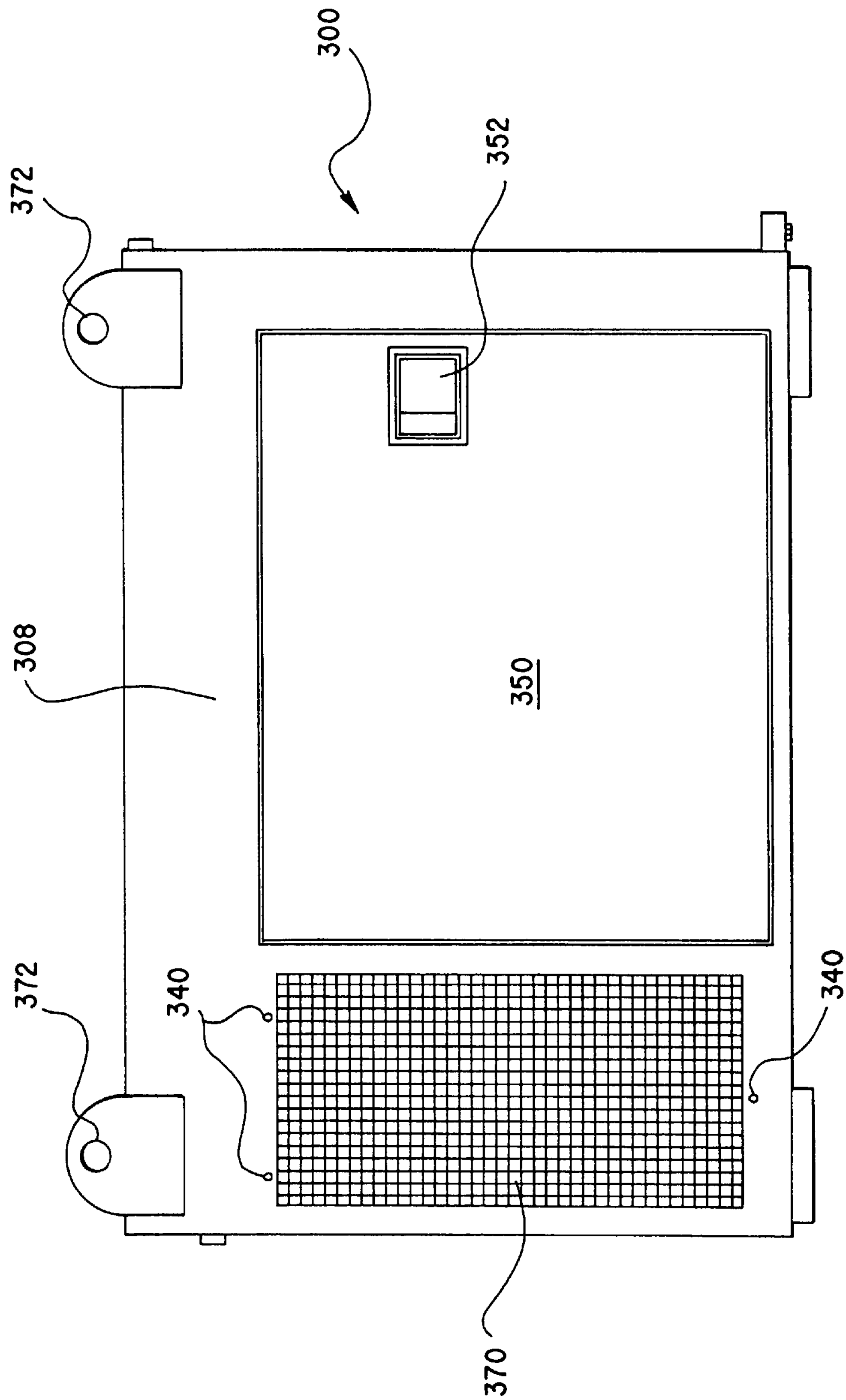
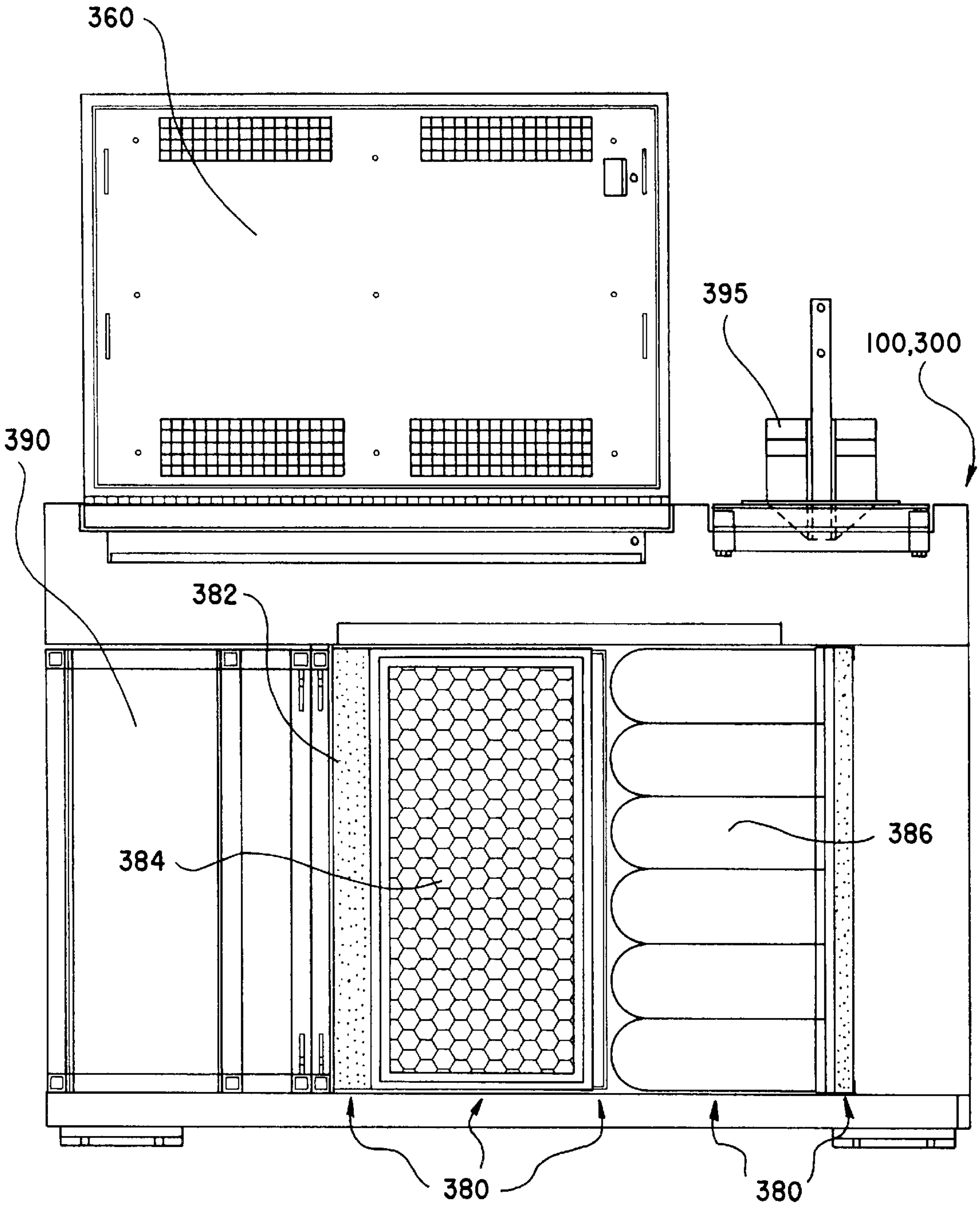


FIG.6

FIG.7



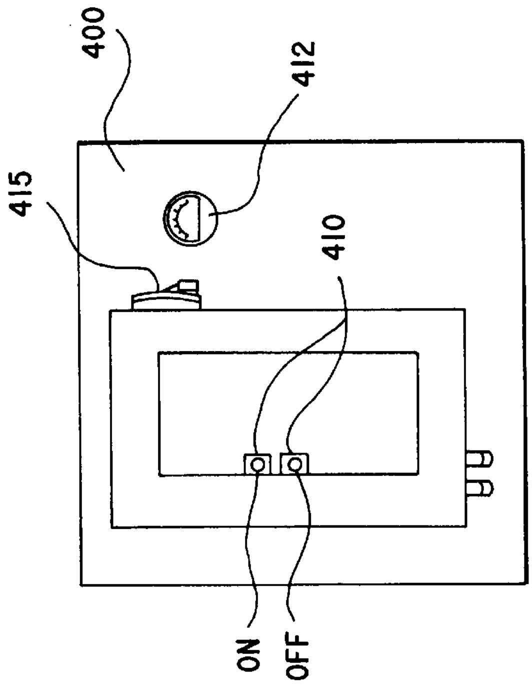


FIG.8A

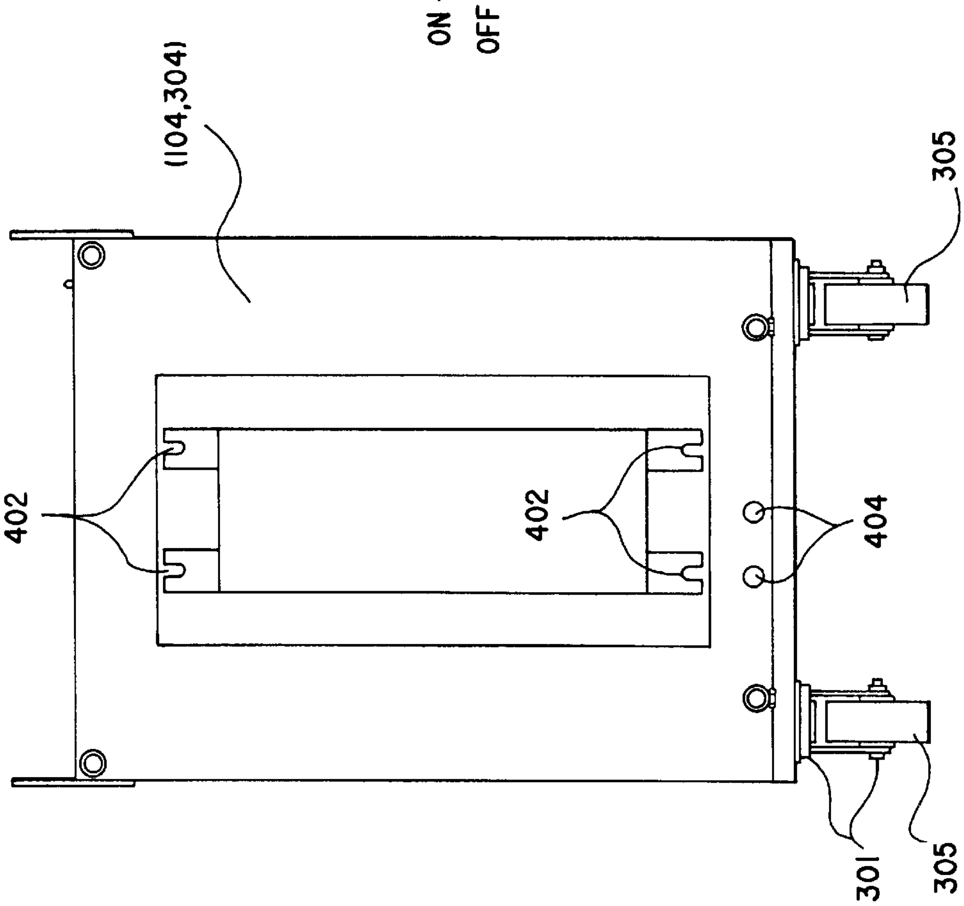
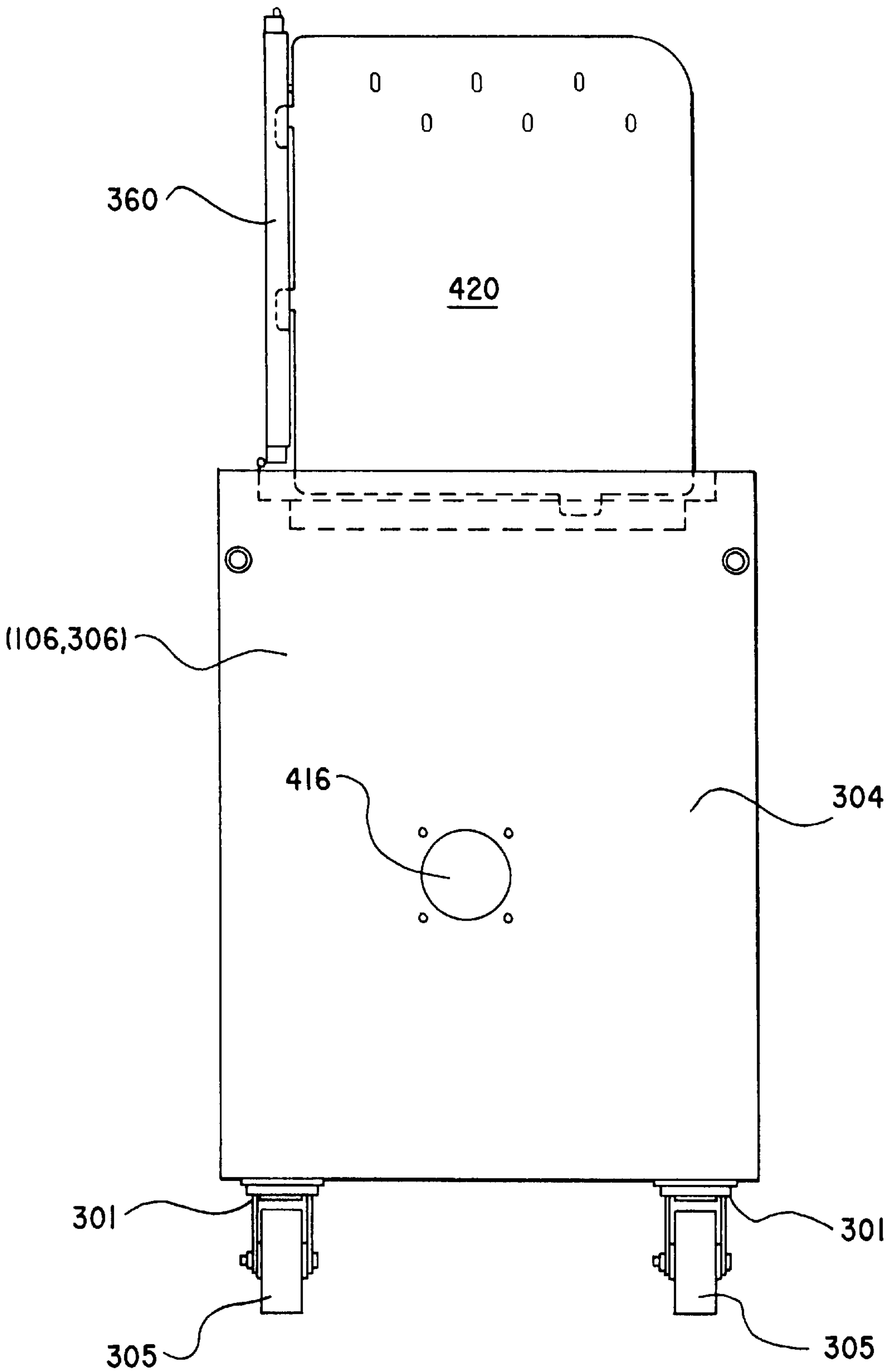
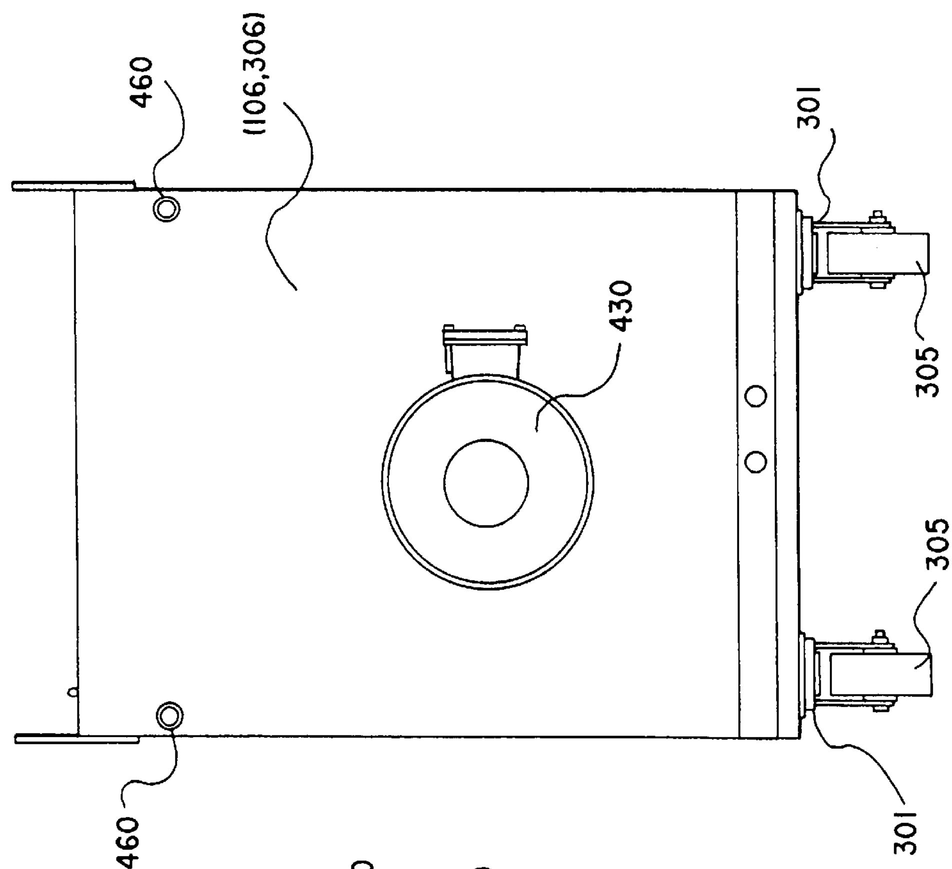


FIG.8

FIG.9

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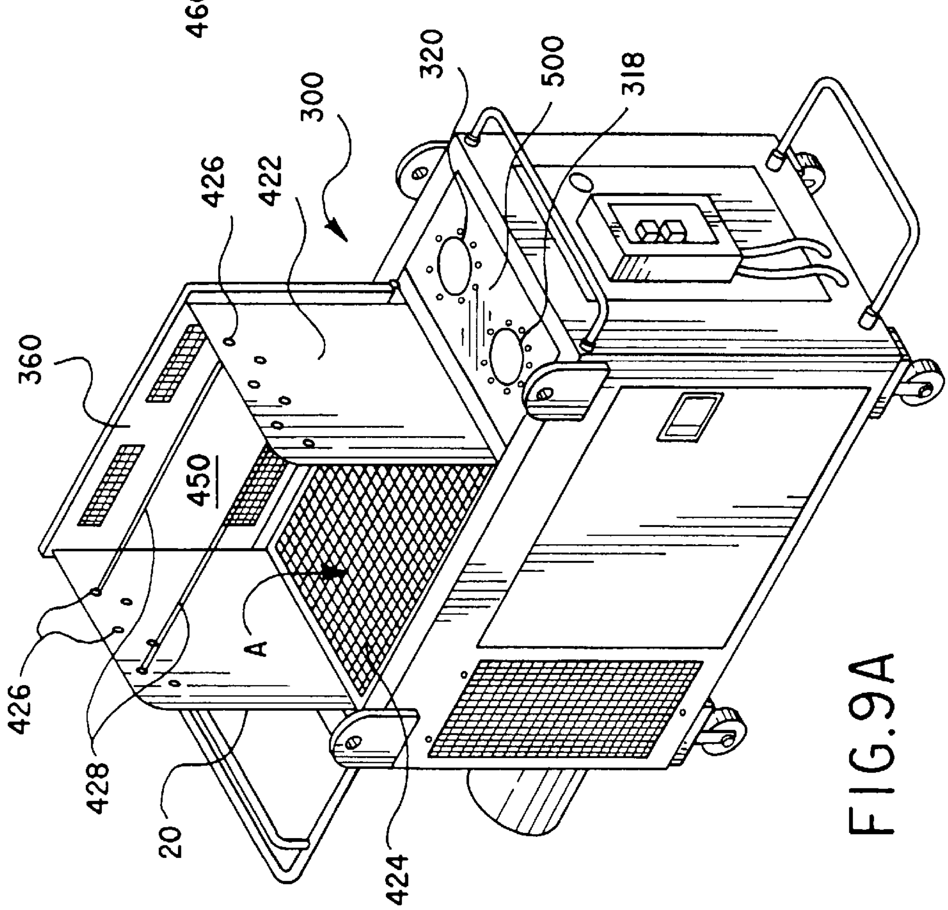
301

FIG.10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20
424

FIG.9A

FIG.13

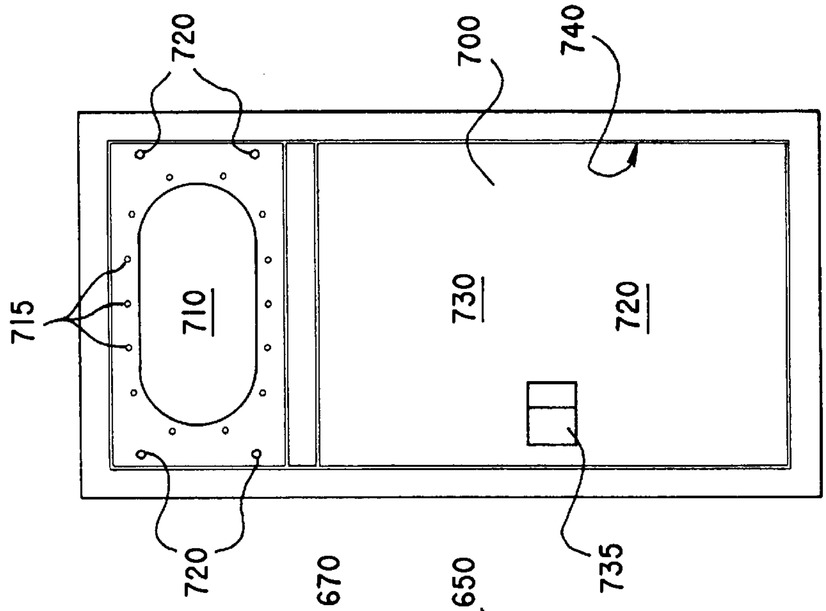


FIG.12

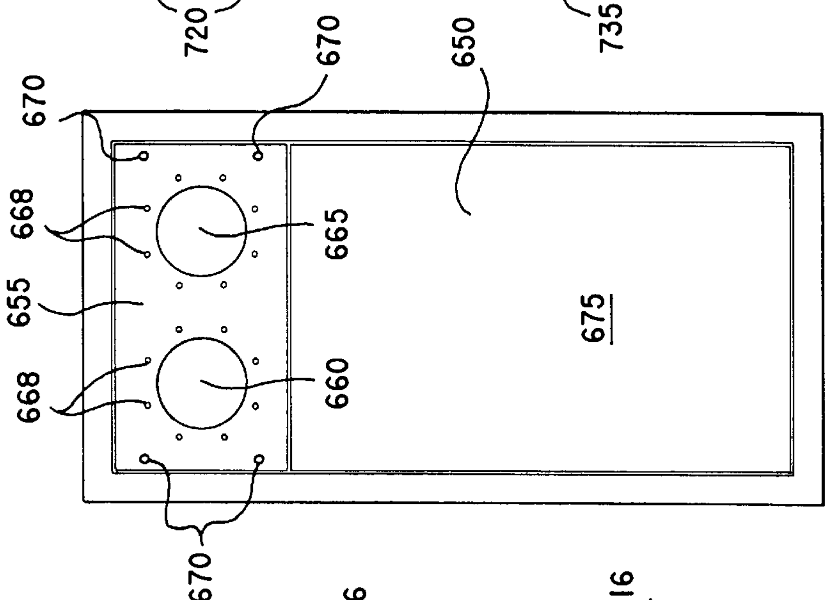


FIG.11

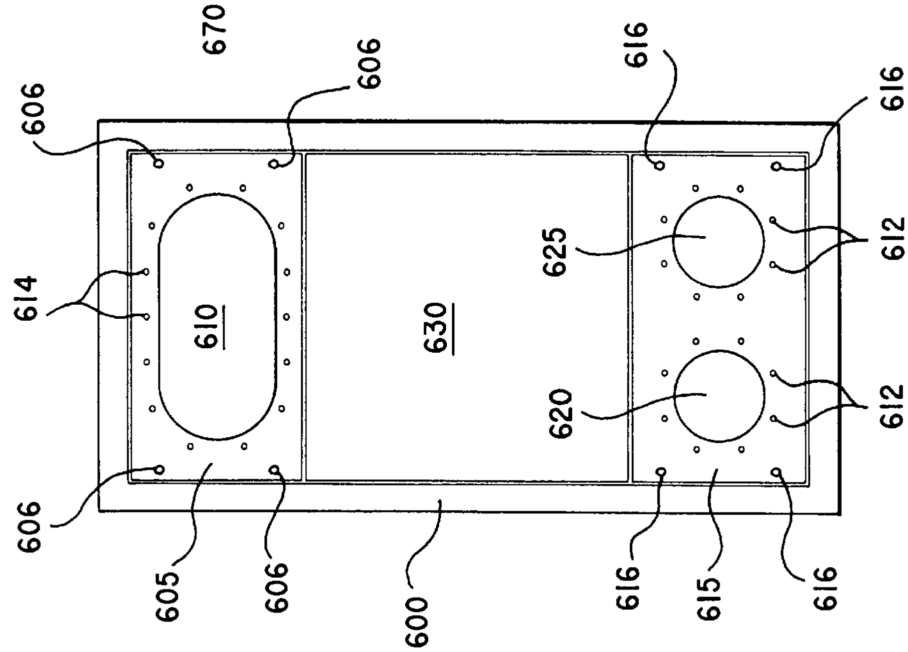


FIG.16

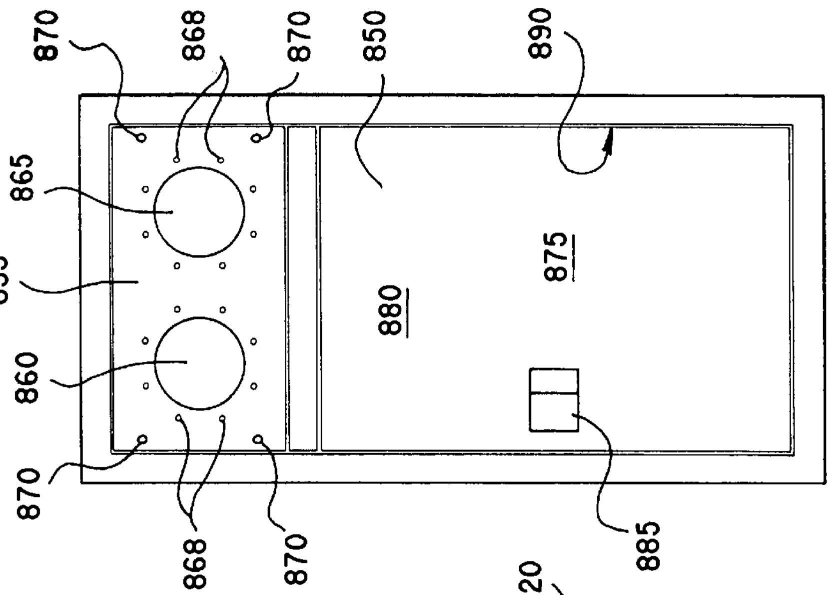


FIG.15

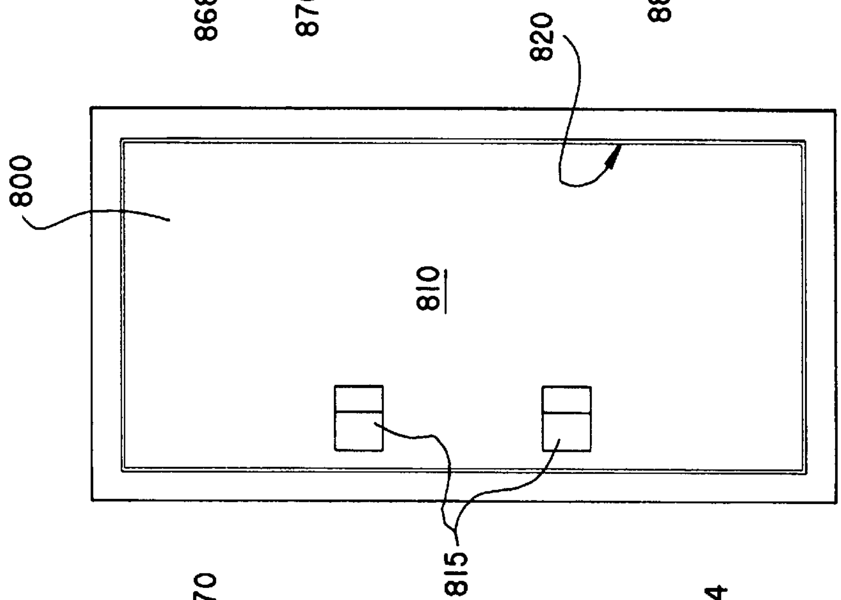
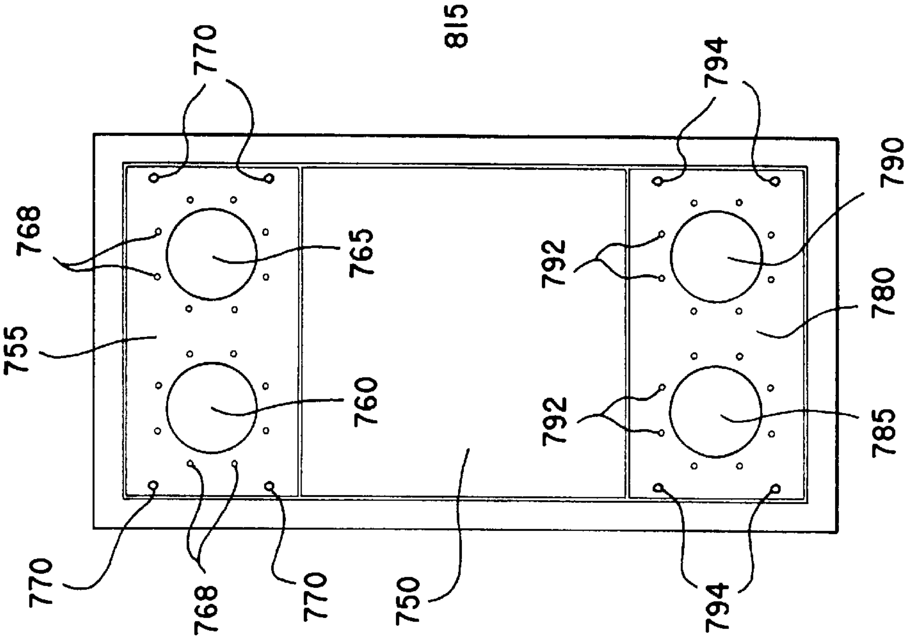


FIG.14



PORTABLE AIRBORNE CONTAMINATION CONTROL SYSTEM INCLUDING A MAIN AND REMOTE UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to overspray and errant particle control devices, and more particularly, to such a system with a main unit and a remote unit which has multiple configurations to permit use in both accessible and inaccessible areas.

2. Summary of the Invention

Equipment developed to capture and filter contaminants generated in the workplace such as welding fumes, sanding and grinding residue, spraying liquids, such as paint which produce odors, toxic fumes, and volatile organic compounds is well known. The majority of this equipment consists of an enclosure, the enclosure housing a motor, blower and a cone, generating the suction necessary to pull the contaminants through a filtering system, often a series of filters, each filter having a specific function. These enclosures are generally fixed.

Capturing liquid contaminants stands separate from fumes or dust contaminants because they must control toxic fumes, volatile organic compounds (VOCs), objectionable odors and wet particles that adhere to the skin, clothing and other equipment in the workplace. For this reason, the area for containment is a booth that will accommodate a car, truck, plane or equipment which prevents aforesaid contaminants into the surrounding environment.

There is a need for a device which is portable, flexible, and treats a wide variety of applications and is unenclosed without presenting harm or danger to the workers or environment. The requirements for this equipment must include an approved method for capturing solid, liquid or gaseous elements including explosive elements. The use of the portable, unenclosed device is focused on the repair, replacement or revamping of devices such as equipment, cars, trucks, planes, military hardware, ships, bridges and the like. The device must also have the capability to be used where welding, sanding and painting (coating) on a smaller scale is being performed, such as small on-the-spot jobs. The capability to evacuate odors and fumes away from the workpiece, no matter where that workpiece is located, is required.

Spraying of coatings, abrasives, and other atomizable substances is a highly efficient way to deliver such substances to a surface or workpiece. A problem encountered is the overpray or errant particles generated by the spraying. This causes environmental issues by placing possibly harmful material into the air. It further endangers the workers spraying the substances, who may breathe the overspray which may be harmful.

This unit is designed for touch-up work or small repair jobs. Often, it is difficult to gain access to the interior of such work-pieces. There is often no viable way to evacuate the overspray, errant particles, fumes and the like from such enclosed areas as inside an aircraft, ship or other large vehicle (bus, train, etc.). This is because the main unit is heavy and bulky and cannot be transported proximal the location being sprayed. By connecting the main unit to a remote unit, one may afford all the benefits of an airborne pollution control device in such an inaccessible or remote location.

The invention is a portable airborne contamination control system with a main unit cabinet and a remote unit. The invention is capable of capturing solid, liquid, and gaseous elements in a single cabinetry which may be adjustable to a variety of applications including the connection to a remote unit. The main airborne contamination control unit is a cabinet including a motor in communication with an air treatment path. The main unit has a variety of configurations enhancing its flexibility. The main unit has the capacity to be connected to a lightweight remote unit. The elongated and flexible duct connecting the main unit to the remote unit may be 50 feet long, its length could be extended by using a higher horsepower motor. The remote unit is highly portable and of a small dimension which permits it to be employed in areas inaccessible to the main unit. The main unit is connected to the remote unit by an elongated and flexible duct. Both the main unit and remote unit have a general cabinet structure with mounting structure designed to receive articulated suction ducts thereon. The articulated suction ducts may be placed proximal a workpiece which is being coated, abraded or treated by spraying. The articulated suction ducts collect overspray, errant particles, odors and fumes and transports them to and through a filter located in the main unit. The filtered air is then exhausted through an exhaust port on the main unit. An elongated duct may be connected to the exhaust port to transport the air to a distant location. The invention permits the main unit to be employed independently on easily accessible locations as well as in conjunction with the remote unit in difficult to reach locations.

By use of the main unit or the remote unit, one may place the articulated suction ducts precisely to the location where the contamination is being generated.

The portable airborne contamination control device with a remote unit basically has two parts. The main unit includes a wheeled cabinet-type housing including a motor-blower, cone, filter, control panels, multiple intake and exhaust ports. The remote unit has a general cabinet-like configuration with multiple intake and exhaust ports. It may be wheeled. The remote unit is in communication with the wheeled housing by an elongated duct.

The main unit includes a housing having a top side wall, a bottom side wall, a right side wall, a left side wall, a front side wall and a back side wall. The walls define a generally rectangular cabinet with an interior and an exterior.

The interior of the cabinet is separated into a plurality of subassemblies. The first subassembly includes a motor-blower. The motor-blower may be chosen to be any of a variety of sizes (horsepower). In the preferred embodiments of the invention, the motor-blowers may be 1, 1.5, 3 & 5 horsepower. Versions of the invention with motors of greater or lesser horsepower have been contemplated. The instant device shown herein is a 5 horsepower explosion-proof motor-blower. Additionally, a motor cage unit is provided which allows precise alignment of the blower with an inlet cone. This maximizes suction efficiency. Further, it permits an interchangeability of motor and blower sizes to meet different suction needs. When using the remote unit, the energy of the motor is essentially transferred from main unit to the articulatable suction ducts connected to the remote unit. There may be energy losses due to the length of the elongated duct connecting the main unit to the remote unit, however, these may be overcome by choosing a strong enough motor-blower.

The second subassembly may be considered to be a filter housing. The filter housing may contain any of a variety of filters depending on the application the device is being specifically employed for. The motor-blower is in commu-

nication with the filter housing. A false bottom is provided proximal the bottom wall. The false bottom permits a power conduit to run from the lower portion of the right side wall to the control panel and then from the control panel to the motor-blower. The false bottom adds structural integrity which would permit the unit to be picked up and moved by a fork-lift, crane, elevator or other lifting device.

The left side wall includes an opening through which a portion of the motor-blower protrudes. The left side wall further includes an opening to permit electrical power for the motor-blower. The left side wall is removably attached to the housing. When the left side wall is removed, the motor-blower may be removed by sliding the motor-blower and its support assembly from the subhousing in which it resides for maintenance. The left side wall further includes a handle mounted on the exterior for pushing the unit. The handle doubles as a storage device for the power cord. The handle extends from the housing a sufficient length to protect the portion of the motor-blower which extends from the exterior of the housing from damage.

The right side wall includes a control panel. A switch may be used on the control panel to turn the motor on or off. The control panel further shows the general condition of the filters, including the life remaining. An overload control is also provided. The right side wall further includes a handle mounted on the exterior for pushing the unit. The handle extends from the housing a sufficient length to protect the control panel from damage.

The bottom side wall includes a plurality of wheels mounted thereto which permits the unit to be easily rolled. The wheels bring the unit off the ground about 5 inches. This would permit the tines of a fork-lift to easily fit underneath the unit. The wheels may be locked in place, securing the unit to a specific location.

The back side wall is a solid and integral wall member.

The front side wall includes a door and an exhaust port. The door is located generally on the right side of the front side wall. The door includes a seal. The door may be opened by actuating a handle. Once opened, access to the filter assembly and the plenum is secured. The exhaust port includes means to mount an exhaust hose thereto. The exhaust hose may be brought to the outside so that any toxic fumes would be transported away from the unit. This exhaust path may safely take the toxic gases, particulates, etcetera to an area acceptable to their disposal and treatment.

The top side wall includes a downdraft access door. The downdraft access door gives access to a chamber which resides beneath the door. Next to the downdraft access door is a first panel.

The first panel may have two or more different configurations. In a first configuration the first panel includes a pair of duct-mounting apertures. The duct-mounting apertures are designed to mate with the articulated suction ducts. The articulated suction ducts include means to permit them to articulate and remain in the position that they are placed. This is the configuration which permits the main unit to operate independently.

In the second configuration the first panel includes a central duct mounting aperture. An elongated central duct is provided. The effective length of the central duct varies with the motor-blower. In the case of the 5 horsepower explosion-proof motor-blower, the elongated central duct has a 10 inch diameter and may be as long as 50 feet. The dimensions of the elongated central duct varies with the horsepower of the motor-blower. The elongated central duct has a first end and a second end. The first end is connected to the central duct-mounting aperture by any conventional means. The second end would be connected to the remote unit. This permits the air pollution control unit to operate in generally inaccessible areas.

The first and second configurations may be changed simply by removing and/or changing panels with the appropriate construction. This may be done easily without special tools. By removal of both configurations, an area for spraying right on the downdraft portion of the main cabinet is provided.

A remote unit is provided. The remote unit includes a top side wall, a bottom side wall, a right side wall, a left side wall, a front side wall and a back side wall. The walls define a generally rectangular cabinet. The right side wall includes a central duct-mounting aperture. The remote unit central duct-mounting aperture is designed to receive the second end of the elongated central duct. The top side wall of the remote unit includes a pair of duct-mounting apertures. These duct-mounting apertures are substantially identical to the first configuration of the first panel. Once again, the duct-mounting apertures are designed to mate with the articulated suction ducts. The articulated suction ducts include means to permit them to articulate and remain in the position that they are placed. It is to be understood that the articulated suction ducts are remote from the main unit in this configuration. The remote unit may be wheeled for ease of movement.

The invention is designed to permit coating, spray painting, or touch-up work to be performed in areas which would be inaccessible to the wheeled housing. The wheeled housing has an approximate weight of 600 lbs. The remote unit weighs as much as 70 lbs. The remote unit is of a much smaller dimension than the wheeled housing and may be independently wheeled or supported by a cart.

The above brief description sets forth rather broadly the more important features of the present invention in order that the detailed description thereof that follows may be better understood, and in order that the present contributions to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject matter of the claims appended hereto.

In this respect, before explaining the invention in detail, it is to be understood that the invention is not limited in its application to the details of the construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood, that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

It is therefore an object of the present invention to provide a portable airborne contamination control system with an independently employable main unit with the capability to be connected with a remote unit.

It is a further object of the present invention to provide a portable airborne contamination control system which may be employed in accessible and inaccessible areas.

It is another object of the present invention to provide a portable airborne contamination control system wherein the main unit has a top portion which has a plurality of configurations, including a first configuration which permits two articulatable suction ducts to be affixed thereto.

It is another object of the present invention to provide a portable airborne contamination control system wherein the main unit has a top portion which has a plurality of configurations, including a second configuration which permits an elongated duct to be affixed thereto, the elongated duct to be connected to a remote unit.

It is another object of the present invention to provide a portable airborne contamination control system wherein the remote unit has a top portion which has a pair of apertures which permits two articulatable suction ducts to be affixed thereto.

It is another object of the present invention to provide a portable airborne contamination control system wherein the remote unit has a side wall which has an aperture to receive the elongated duct from the main unit.

It is another object of the present invention to provide a portable airborne contamination control system wherein the main unit has a top portion which has a plurality of configurations, including a third configuration which includes a downdraft area which permits small items to be treated (sprayed, welded, coated etcetera.) directly on the main unit.

These, together with still other objects of the invention, along with the various features of novelty which characterize the invention, are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be made to the accompanying drawings and descriptive matter in which there are illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and the above objects as well as objects other than those set forth above will become more apparent after a study of the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

FIG. **1** is a view of the airborne pollution control system showing the main unit connected to the remote unit.

FIG. **2** is a view of the airborne pollution control system showing the main unit in one of a plurality of stand-alone configurations.

FIG. **3** is a view of the remote unit of the airborne pollution control system.

FIG. **4**A is a view of the end of one of the articulated suction ducts, showing attachment means.

FIG. **4**B is a view of the pre-filter and pre-filter support mounted to the end of one of the articulated suction ducts.

FIG. **5** is a top view of the main unit of the portable airborne pollution control system showing one of the six preferred configurations, as shown in FIG. **11** through FIG. **16**.

FIG. **6** is a front view of the main unit of the portable airborne pollution control system.

FIG. **7** is a cutaway front view of the main unit of the portable airborne pollution control system showing the replaceable filter configuration, motor cage, and top door in the open position.

FIG. **8** is a first side view of the portable airborne pollution control system, showing substructure required to support the control panel.

FIG. **8**A is a view of the control panel which would be located atop the first side wall of the portable airborne pollution control system as shown in FIG. **8**.

FIG. **9** is a second side view of the portable airborne pollution control system showing an aperture to receive a portion of the motor there through, and additionally, shows one wall of an enclosure which may be formed on the top of the main unit, when in one of the stand-alone configurations.

FIG. **9**A shows a view of a spraying enclosure which is formed on the top of the main unit of the airborne pollution control device which permits touch-up and small jobs to be performed directly on the main unit.

FIG. **10** is a second side view of the portable airborne pollution control system showing a portion of the motor there through.

FIG. **11** is a top view of the main unit in a first configuration.

FIG. **12** is a top view of the main unit in a second configuration.

FIG. **13** is a top view of the main unit in a third configuration.

FIG. **14** is a top view of the main unit in a fourth configuration.

FIG. **15** is a top view of the main unit in a fifth configuration.

FIG. **16** is a top view of the main unit in a sixth configuration.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the drawings, a portable airborne pollution control system with a main unit and a remote unit embodying the principles and concepts of the present invention will be described.

Turning initially to FIG. **1**, the portable airborne pollution control system **10** is shown. The portable airborne pollution control system **10** includes a main unit **100** and a remote unit **200**. The main unit **100** has a general cabinet like structure, including a top side wall **102**, a right side wall **104**, a left side wall **106**, a front side wall **108**, a rear side wall **110** and a bottom side wall **112**. The bottom side wall **112** includes wheels **105**, which permits the main unit **100** to be rolled. Braking means are provided to secure the wheels **105** from rotation. This permits the main unit **100** to be rolled to a desired location and then secured in that location by engaging the braking means. The braking means are conventional and may be easily engaged. Other structure for lifting, pushing and transporting the main unit **100** is present and will be discussed below.

The top side wall **102** has a frame like substructure which permits its configuration to be easily altered. Top side wall **102** includes a downdraft door **107** with a downdraft door handle **109**. When the downdraft door handle **109** is engaged, the downdraft door **107** may be opened and placed in a vertical relation to the top side wall **102**. FIGS. **11–16** show the preferred configurations and will be discussed below. FIG. **1** shows the main unit **100** with a top side wall **102** showing the configuration as shown in FIG. **13**.

The interior of the main unit **100** includes a motor-blower, a filter system and an air passageway. The air passageway includes an air intake port **122** and an air exhaust port **114**.

The motor-blower causes untreated air to enter the main unit **100** through the air intake port **122**, pass through the filter system where the untreated air is treated, and then exhausts the treated air through an exhaust port **114** located on the front side wall **108**.

The air intake port **122** is connected to the first end **52** of the elongated duct **50**. Means to mount the first end **52** of the elongated duct **50** to the air intake port **122** are provided. The mounting means provided here may be one of any conventional and well-known mounting, connection and securing means.

The air exhaust port **114** includes mounting means **116** to secure a mask **118** and exhaust duct **120**. The mask **118** completely covers the exhaust port **114** and is configured in a generally tapered fashion to mate to the exhaust duct **120** within specific tolerances. This permits any toxic fumes etcetera which may not be able to be treated by the organic filter system to be transported to a remote location. The remote location may include means to further treat and dispose of the exhaust. Since it is taken to a location away from the workers, worker safety is enhanced.

The top side wall **102** has an air intake port **122**. The air intake port **122** is configured as an aperture. The air intake port **122** includes mounting means to secure a first end **52** of an elongated duct thereto.

In FIG. **1**, the main unit **100** is shown connected to the remote unit **200** by an elongated duct **50**. The elongated duct **50** has a first end **52** and a second end **54**. FIG. **1** exemplifies the portable airborne pollution control system **10** with the main unit **100** being in communication with the remote unit **200** through an air passageway formed by elongated duct **50**.

The remote unit **200** also has a cabinet-like structure, but it is significantly smaller in dimension than the main unit **100**. The remote unit **200** may be wheeled **205**, may be placed on a trolley or cart, or may just reside atop a surface. The remote unit **200** includes a top side wall **202**, a right side wall **204**, a left side wall **206**, a front side wall **208**, a rear side wall **210** and a bottom side wall **212**. The interior of the remote unit is preferably hollow, although filtering units or a remote air motor may be present in certain applications. The left side wall **206** includes an aperture which acts as a remote unit air exhaust port **214**. The remote unit air exhaust port **214** includes mounting means **214** to secure the second end **54** of the elongated duct **50** thereto.

The remote unit **200** top side wall **202** has a first aperture (first air intake port) **218** and a second aperture (second air intake port) **220** located thereon. A first articulated suction duct **222** includes a proximal side **224** and a distal side **226**. A second articulated suction duct **232** includes a proximal side **234** and a distal side **236**. The first articulated suction duct **222** proximal side **224** is affixed to the first aperture (first air intake port) **218** by the articulated duct mounting means. The second articulated suction duct **232** proximal side **234** is affixed to the second aperture (second air intake port) **220** by the articulated duct mounting means.

The articulated duct mounting means which secure the first articulated suction duct **222** and the second articulated suction duct **232** to the remote unit **200** may be one of any conventional and well-known mounting, connection and securing means. The dual articulated duct receiving panel is the top side wall **202** of the remote unit **200**. This structure is generally identical to the dual articulated duct receiving panel shown in FIG. **11**, FIG. **12**, FIG. **14** and FIG. **16**. The dual articulated duct receiving panel is a common element and is dimensioned appropriately to permit it to be employed on the top side wall **102** of the main unit **100** as well as the top side wall **202** of the remote unit **200**.

FIG. **2** shows the portable airborne pollution control system **295** in a second configuration. In the second configuration, the portable air pollution control system **295** just includes the main unit **300** in a stand-alone role. The main unit **300** again has a general cabinet-like structure, including a top side wall **302**, a right side wall **304**, a left side wall **306**, a front side wall **308**, a rear side wall **310** and a bottom side wall **312**.

The bottom side wall **312** includes wheels **305**, which permits the main unit **300** to be rolled. Braking means are provided to secure the wheels **305** from rotation. This permits the main unit **300** to be rolled to a desired location and then secured in that location by engaging the braking means. The braking means are conventional and may be easily engaged. Other structure for lifting, pushing and transporting the main unit **300** is present, such as reinforcement to permit the main unit to be lifted by a forklift, scissor lift or elevator.

The top side wall **302** has a frame-like substructure which permits its configuration to be easily altered. FIG. **16** show the configuration present on the top side wall **302** in FIG. **2**. In the stand-alone embodiment, all six configurations shown in FIGS. **11–16** may be used. To convert from one configuration to another requires simple tools and the correct model. By removing or exchanging the panels one may easily alter the configuration.

The interior of the main unit **300** includes a motor-blower, a filter system and an air passageway. It has a first aperture (first air intake port) **318** and a second aperture (second air intake port) **320** located thereon. A first articulated suction duct **322** includes a proximal end **324** and a distal end **326**. A second articulated suction duct **332** includes a proximal end **334** and a distal end **336**. The first articulated suction duct **322** proximal end **324** is affixed to the first aperture (first air intake port) **318** by the articulated duct mounting means. The second articulated suction duct **332** proximal end **334** is affixed to the second aperture (second air intake port) **320** by the articulated duct mounting means.

The articulated duct mounting means which secure the first articulated suction duct **322** and the second articulated suction duct **332** to the main unit **300** may be one of any conventional and well-known mounting, connection and securing means. The dual articulated duct receiving panel is located on the top side wall **302** of the main unit **300**. This structure is generally identical to the dual articulated duct receiving panel shown in FIG. **11**, FIG. **12**, FIG. **14** and FIG. **16**.

The motor-blower causes untreated air to enter the main unit **300** through the first articulated suction duct **322** and the second articulated suction duct **332**, then through the first aperture **318** and the second aperture **320**, then passes through the filter system where the untreated air is treated, and then exhausts the treated air through an exhaust port **314** located on the front side wall **308**.

The first air intake port **318** and the second air intake port **320** are connected to the proximal end **324** of the first articulated suction duct **322** and the proximal end **334** of the second articulated suction duct **332** respectively. Means to mount the proximal end **324** of the first articulated suction duct **322** to the first air intake port **318** are provided. Means to mount the proximal end **334** of the second articulated suction duct **332** to the second air intake port **320** are also provided. The aforementioned mounting means provided here may be one of any conventional and well-known mounting, connection and securing means.

The exhaust port **338** includes mounting means **340** to secure a mask **342** and exhaust duct **344**. The mask **318**

completely covers the generally rectangular exhaust port **338** and is configured in a tapered fashion to mate to the exhaust duct **344** within specific airtight tolerances. This permits any toxic fumes etcetera which may not be able to be treated by the organic filter system to be transported to a remote location. The remote location may include means to further treat and dispose of the exhaust. Since it is taken to a location away from the workers, worker safety is enhanced.

Located on the right side of the front side wall is a front door **350** which is secured and opened by a latching handle **352**. The front door **350** is surrounded by a gasket to maintain airtight integrity. Behind the front door **350** is a filter system and motor and will better be described in FIG. **7**.

Located on the top side wall **302** is a downdraft door **360**. The downdraft door **360** also has a gasket surrounding its perimeter to maintain airtight integrity. The downdraft door **360** is opened and secured by a latching handle **362**. Located below the downdraft door **360** is a region which is in the air passageway prior to the exhaust port **338**. This region has a heavy screen that may support a prefilter and a means to set up right and left panels to form an enclosure about the region to permit spraying of smaller objects directly on the enclosure with the motor-blower taking away any overspray, errant particles, fumes etcetera. This will be shown in greater detail in the description of FIG. **9** and FIG. **9**A.

Referring now specifically to FIG. **3**, a view of the remote unit **200** is shown. The remote unit **200** has been referred to as a remote plenum. Again, the remote unit **200** also has a cabinet-like structure, but it is significantly smaller in dimension than the main unit **100**. The remote unit **200** may be wheeled **205**, may be placed on a trolley or cart, or may just reside atop a surface. The remote unit **200** includes a top side wall **202**, a right side wall **204**, a left side wall **206**, a front side wall **208**, a rear side wall **210** and a bottom side wall **212**. The interior of the remote unit is preferably hollow, although filtering units or a remote air motor may be present in certain applications. The left side wall **206** includes an aperture which acts as a remote unit air exhaust port **214**. The remote unit air exhaust port **214** includes mounting means **214** to secure the second end **54** of the elongated duct **50** thereto.

The remote unit **200** top side wall **202** has a first aperture (first air intake port) **218** and a second aperture (second air intake port) **220** located thereon. A first articulated suction duct **222** includes a proximal end **224** and a distal end **226**. A second articulated suction duct **232** includes a proximal end **234** and a distal end **236**. The first articulated suction duct **222** proximal end **224** is affixed to the first aperture (first air intake port) **218** by the articulated duct mounting means. The second articulated suction duct **232** proximal end **234** is affixed to the second aperture (second air intake port) **220** by the articulated duct mounting means.

The articulated duct mounting means which secure the first articulated suction duct **222** and the second articulated suction duct **232** to the remote unit **200** may be one of any conventional and well-known mounting, connection and securing means. The dual articulated duct receiving panel is the top side wall **202** of the remote unit **200**. This structure is generally identical to the dual articulated duct receiving panel shown in FIG. **11**, FIG. **12**, FIG. **14** and FIG. **16**. The dual articulated duct receiving panel is a common element and is dimensioned appropriately to permit it to be employed on the top side wall **102** of the main unit **100** as well as the top side wall **202** of the remote unit **200**.

There is a certain comparison which should be made between elements of the remote unit **200** and elements of the stand alone main unit **300**. First, the articulated suction ducts (**222**, **232**, **322**, & **334**) are identical and interchangeable. Second, the mounting plate to which the articulated suction ducts are mounted are the same mounting plate. This gives one a sense of the scale of the main unit (**100** & **300**) to the remote unit **200**.

Referring now specifically to FIGS. **4**A & **4**B, several views of a generic articulated suction duct distal end **402** is shown. The end view **400** shows a hollow interior region **404** which is centrally located. This region **404** has a door which may be opened or shut by a manual damper **410** located on the articulated suction duct **412**. This makes the articulated suction duct **412** able to be airtight or permit air to pass by the vacuum energy caused by the motor-blower. Velcro tabs **408** are located as shown thereon to attach a filter frame **414** which holds a filter **416** therein. This filter assembly **420** creates a larger surface area for particulates, errant particles, overspray, etcetera to be collected. Further, the filter **416** will cause many of the airborne particles to be collected at the ends of the articulated suction ducts which helps extend the lifetime of the filter system located inside the main unit (**100** or **300**). Some filters have material properties which permit them to be attached directly to the velcro tabs without the filter frame **414**.

FIG. **5** shows a top view of the main unit in the stand-alone configuration. The first air intake port **318** and the second air intake port **320** are located on the mounting plate **500**. Mounting plate **500** is secured by fasteners **502** which secure mounting plate **500** to the main unit **300**. Mounting plate **500** may be easily interchanged with a mounting plate having a single aperture which would convert this to the system configuration, i.e.: switching from the stand-alone configuration to one where the main elongated duct **50** connects the main unit **100** to the remote unit **200**. A plurality of handles **510**, **512**, & **514** are provided for pushing the main unit, for guarding extended portions, such as the motor, against hitting a wall as well as storing power cables thereon. The downdraft door **360** and opening latch **362** are also shown. To open the downdraft door **360**, latch **362** is pulled, and the downdraft door **360** is moved rearwardly about hinge **364** until it is in a completely upright position, perpendicular to the top side wall **302**.

Referring now specifically to FIG. **6** the front side wall **308** of the main unit **300** is shown. The front door **350** is shown with the latching handle **352**. Located about the interior perimeter of the front door **350** is a gasket which makes the front door **350** air tight. The exhaust grill **370** is shown sans mask **342** and exhaust duct **344**. Mounting means **340** are provided generally about the perimeter of the exhaust grill to attach the mask **342** thereto, by affixing the mask **342** by fasteners. There are circumstances when the mask **342** and exhaust duct **344** are not required. Such circumstances include, but are not limited to, using the main unit **300** outdoors, using the portable airborne pollution control system **10** while collecting non-harmful errant particles, overspray and the like. Lifting eyes **372** are provided on the corners of the front side wall **308** as well as the rear side wall **310** (not shown). This permits the main unit (**100**, **300**) to be lifted by a crane or other system which can mate with the lifting eyes and raise the main unit (**100**, **300**).

Referring now to FIG. **7**, a view of the main unit (**100**, **300**) with the front side wall **308** being removed is shown. The downdraft door **360** is open to its full extent. The filter system **380** is shown generally on the right side of FIG. **7**.

The filter system **380** includes a first filter (known as a pocket filter) **386**, a HEPA filter **384** and a third filter (charcoal filter) **382**. Mounting structure is included in the filter system **380** to permit the filters (**382, 384, & 386**) to be easily replaced once they have reached their lifetime.

A motor cage **390** is shown generally on the left side of FIG. **7**. The motor cage **390** is slidable in order to facilitate the maintenance, repair and replacement of the motor-blower, motor-cone or other motor-related hardware. Element **395** in FIG. **7** is a mounting bracket which is used for mounting the articulated suction ducts.

Referring now specifically to FIG. **8** and FIG. **8**A, the right side wall (**104, 304**) is shown. In FIG. **8** the right side wall **304** is shown prior to the mounting of the control panel **400**. Wheels **305** are shown with their wheel mounting structure **301**. Similar wheels **305** and wheel mounting structure **301** are located on the left side wall (**106, 306**). Control panel mounting elements **402** are shown. Apertures **404** permit control panel **400** electrical wires to pass through the bottom side wall (**112, 312**) to control the motor-blower, plus permit sensors such as pressure sensors to communicate between the sensor and the gauge shown on the control panel **400**.

FIG. **8**A shows the control panel **400**. Indicator lights **410** are provided on the face of the control panel **400**. A pressure gauge **412** is provided on the right side wall **304** as well. The pressure gauge **412** is connected to a pressure sensor located within the main unit **100**. An on-off switch **415** is provided.

Referring now specifically to FIG. **9**, a view of the left side wall (**106, 306**) is shown. Wheels **305** are shown with their wheel mounting structure **301**. The downdraft door **360** is shown in its open position, where it is mated with a left panel **420**. A right panel is shown in FIG. **9**A, which defines an enclosure and will be addressed in the discussion of FIG. **9**A. A portion of the motor-blower extends through an aperture **416** present in the left side wall (**106, 306**).

Referring now specifically to FIG. **9**A, a view of the main unit **300** with the spraying enclosure **450** is shown. The spraying enclosure **450** is defined by the three vertical panels, the downdraft door **360** (in vertical position), the left panel **420** and the right panel **422**. To the right of the right panel **422** is mounting plate **500** to which the articulated ducts would be attached. In this configuration, the apertures (**318, 320**) would be secured. Alternatively, a mounting plate with no apertures may be secured in the place of the mounting plate **500**.

An item to be sprayed or have touch-up work performed upon it would be placed on the screen **424** which defines the floor of the spraying enclosure **450**. Arrow A defines the direction of the downdraft caused by the motor-blower, which would cause any overspray or errant particles generated to be suctioned through the filter system and then to the exhaust. Both the left panel **420** and the left panel **422** have a plurality of apertures **426** located thereon. The apertures **426** are located in such a fashion to suspend a rod **428** intermediate their location, thus permitting an article of work to be suspended from the aforesaid rod **428**. The left panel **420** and the right panel **422** may be vertically mounted about the right and left perimeters of the screen **424** respectively.

Referring now specifically to FIG. **10**, the left side wall (**106, 306**) is shown. Wheels **305** are shown with their wheel mounting structure **301**. Similar wheels **305** and wheel mounting structure **301** are located on the right side wall (**104, 304**) as indicated in the discussion of FIG. **8**. Element **460** is a handle **514** which protrudes horizontally from the left side wall (**106, 306**) and can best be seen in FIG. **5**. The length of the handle **514** protects the motor-blower unit **430** which also protrudes horizontally from the left side wall (**106, 306**) but not to the same degree as the handle **514**. If the main unit (**100, 300**) should roll and hit a wall or the like, the impact would be on the handle **514** and not on the exposed portion of the motor-blower unit **430**.

FIGS. **11–16** diagram different configurations for the top side wall (**102, 302**) for the main unit. Some are better suited to be used with the portable airborne pollution control system **10** with the main unit **100**, (this has the top side wall **102**), whereas others are best suited to be used with the main unit **300** in the stand-alone configuration (having the top side wall **302**).

FIG. **11** shows a first top side wall configuration **600**. Top side configuration **600** has a first side **605** with a central aperture **610**, the central aperture **610** designed to be mated with a duct to be connected to the remote unit (not shown). Small fastener receiving apertures **614** will receive fasteners to secure the duct and any ancillary duct mating structure to the central aperture **610**.

Top side configuration **600** has a second side **615** which has a first aperture **620** and a second aperture **625** designed to be mated with the first articulated suction duct and the second articulated suction duct (not shown). Small fastener receiving apertures **612** will receive fasteners to secure the articulated suction ducts and any ancillary duct mating structure to the first aperture **620** and the second aperture **625**.

The central element **630** is a solid air-proof element, which in this configuration is secured to a framework located in the body of the main unit **100**.

First side **605** is secured to the main unit **100** by a plurality of removable fasteners placed through plate apertures **606**. The first side **605** is a plate like structure which mounts to a framework which exists in the area below where the first side **605** is mounted. The fasteners may be one of any type of conventional threaded fasteners.

Second side **615** is secured to the main unit by a plurality of removable fasteners placed through plate apertures **616**. The second side **615** is also a plate-like structure which mounts to a framework which exists in the area below where the second side **615** is mounted. The fasteners may be one of any type of conventional threaded fasteners.

Both first side **605** and second side **615** may be removed, interchanged or replaced with a plate having no large centrally disposed apertures with the exception of the small fastener receiving apertures. This would make either plate air-proof as well. This shows how versatile the top side wall of the unit can be.

FIG. **12** shows a second top side wall configuration **650**. Second top side configuration **650** has a first side **655** which has a first aperture **660** and a second aperture **665** designed to be mated with the first articulated suction duct and the second articulated suction duct (not shown). Small fastener receiving apertures **668** will receive fasteners to secure the articulated suction ducts and any ancillary duct mating structure to the first aperture **660** and the second aperture **665**.

First side **655** is secured to the main unit **100** by a plurality of removable fasteners placed through plate apertures **670**. The first side **655** is a plate-like structure which mounts to a framework which exists in the area below where the first side **655** is mounted. The fasteners may be one of any type of conventional threaded fasteners. The first side **655** may be replaced with a plate-like structure having the configuration

shown in FIG. **11**, of the first side **605** of the first top side wall configuration **600**. This shows the versatility of the invention.

The second side **675** of the second top side wall configuration **650** is a table top. This table top may support objects and tools, is secured in place and is air-proof.

FIG. **13** shows a third top side wall configuration **700**. Third top side configuration **700** has a first side **705**. First side **705** includes a generally centrally disposed aperture **710**, the central aperture **710** designed to be mated with a duct to be connected to the remote unit (not shown). Small fastener receiving apertures **715** will receive fasteners to secure the duct and any ancillary duct mating structure to the first aperture **710**.

First side **705** is secured to the main unit **100** by a plurality of removable fasteners placed through plate apertures **720**. The first side **705** is a plate-like structure which mounts to a framework which exists in the area below where the first side **705** is mounted. The fasteners may be one of any type of conventional threaded fasteners. The first side **705** may be replaced with a plate like structure having the configuration shown in FIG. **12**, of the first side **655** of the second top side wall configuration **650**. This further shows the versatility of the invention.

The third top side wall configuration **700** includes a second side **725**. The second side **725** is the downdraft door **730**. A downdraft door handle **735** is provided. By actuating the downdraft door handle **735**, the downdraft door **730** may be opened, pivoting about hinges located along the line **740**. Once the downdraft door **730** is perpendicular to the third top side wall **700**, it is secured in that vertical relation. This would begin to establish the downdraft area which is shown in FIGS. **9** and **9**A.

FIG. **14** shows a fourth top side wall configuration **750**. The fourth top side wall configuration **750** has a first side **755** which has a first aperture **760** and a second aperture **765** designed to be mated with the first articulated suction duct and the second articulated suction duct (not shown). Small fastener receiving apertures **768** will receive fasteners to secure the articulated suction ducts and any ancillary duct mating structure to the first aperture **760** and the second aperture **765**.

First side **755** is secured to the main unit **100** by a plurality of removable fasteners placed through plate apertures **770**. The first side **755** is a plate-like structure which mounts to a framework which exists in the area below where the first side **755** is mounted. The fasteners may be one of any type of conventional threaded fasteners. The first side **755** may be replaced with a plate-like structure having the configuration shown in FIG. **11**, of the first side **605** of the first top side wall configuration **600**.

The fourth top side configuration **750** has a second side **780** which has a third aperture **785** and a fourth aperture **790** designed to be mated with a third articulated suction duct and a fourth articulated suction duct (not shown). Small fastener receiving apertures **792** will receive fasteners to secure the articulated suction ducts and any ancillary duct mating structure to the third aperture **785** and the fourth aperture **790**.

Second side **780** is secured to the main unit **100** by a plurality of removable fasteners placed through plate apertures **794**. The second side **780** is a plate-like structure which mounts to a framework which exists in the area below where the second side **780** is mounted. The fasteners may be one of any type of conventional threaded fasteners.

The first side **755** or second side **780** may be replaced with a plate-like structure having the single duct configuration shown in FIG. **11**, of the first side **605** of the first top side wall configuration **600**.

Intermediate the first side **755** and the second side **780** is a middle element **796**. The middle element **796** is a flat portion which may act as a table top. This table top may support objects and tools, is secured in place and is air-proof.

FIG. **15** shows a fifth top side wall configuration **800**. In the fifth top side wall configuration **800**, the main unit functions as a stand-alone unit. It includes a downdraft door **810** which covers the entire top portion of the main unit. A single or plurality of downdraft door handles **815** are provided. When the downdraft door handles **815** are actuated, the downdraft door **810** would be opened and rotated about hinge elements located on line **820**. After the downdraft door **810** is opened and is placed in a perpendicular relation to the main unit, a right and left panel would be affixed, forming the spraying enclosure as shown in FIGS. **9** and **9**A.

FIG. **16** shows a sixth top side wall configuration **850**. Sixth top side configuration **850** has a first side **855** which has a first aperture **860** and a second aperture **865** designed to be mated with the first articulated suction duct and the second articulated suction duct (not shown). Small fastener receiving apertures **868** will receive fasteners to secure the articulated suction ducts and any ancillary duct mating structure to the first aperture **860** and the second aperture **865**.

First side **855** is secured to the main unit **100** by a plurality of removable fasteners placed through plate apertures **870**. The first side **855** is a plate-like structure which mounts to a framework which exists in the area below where the first side **855** is mounted. The fasteners may be one of any type of conventional threaded fasteners. The first side **855** may be replaced with a plate like structure having the configuration shown in FIG. **13**, showing the ease in which the configuration of FIG. **13** may be replaced with the configuration of FIG. **16**.

The sixth top side wall configuration **850** includes a second side **875**. The second side **875** is the downdraft door **880**. A downdraft door handle **885** is provided. By actuating the downdraft door handle **885**, the downdraft door **880** may be opened, pivoting about hinges located along the line **890**. Once the downdraft door **880** is perpendicular to the sixth top side wall **850**, it is secured in that vertical relation. This would begin to establish the downdraft area which is shown in FIGS. **9** and **9**A.

It is apparent from the above that the present invention accomplishes all of the objectives set forth by providing a portable airborne contamination control system with an independently employable main unit with the capability to be connected with a remote unit wherein the main unit may be deployed in accessible areas and the remote unit may be deployed in inaccessible areas.

With respect to the above description, it should be realized that the optimum dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to those skilled in the art, and therefore, all relationships equivalent to those illustrated in the drawings and described in the specification are intended to be encompassed only by the scope of appended claims.

While the present invention has been shown in the drawings and fully described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that many

modifications thereof may be made without departing from the principles and concepts set forth herein. Hence, the proper scope of the present invention should be determined only by the broadest interpretation of the appended claims so as to encompass all such modifications and equivalents.

I claim:

1. A portable airborne contamination control system comprising:

a main unit, said main unit having a motor, an inlet port, an exhaust port, and a first weight,

an elongated duct, said elongated duct having a first side and a second side,

a remote unit, said remote unit having an exit port, a second weight, a first entrance port and a second entrance port, a first articulated suction duct attached to said first entrance port and a second articulated suction duct attached to said second entrance port,

said elongated duct first side connected to said main unit inlet port, said elongated duct second side connected to said remote unit said exit port,

wherein said first weight significantly greater than said second weight, and

whereby said remote unit is adapted to be placed in an area which is inaccessible to the main unit, said first articulated suction duct and said second articulated suction duct are placed proximal to a workpiece being treated in such a manner where when overspray and errant particles are generated, the overspray and errant particles are being suctioned through said first articulated suction duct and said second articulated suction duct, through said remote unit, through said elongated duct, into said main unit and exhausted through said exhaust port.

2. A portable airborne contamination control system as claimed in claim **1** wherein said first articulated suction duct

has a proximal side and a distal side, and said second articulated suction duct has a proximal side and a distal side, said first articulated suction duct proximal side is attached to said first entrance port, and said second articulated suction duct is attached to said second entrance port.

3. A portable airborne contamination control system as claimed in claim **2** wherein said first articulated arm distal side includes a first mounting means adapted for mounting a first filter thereto, and said second articulated arm distal side includes a second mounting means adapted for mounting a second filter thereto, whereby said first filter and said second filter both act as a pre-filter, collecting the overspray and the errant particles in said first filter and said second filter, said first filter and said second filter being close to the workpiece being treated.

4. A portable airborne contamination control system as claimed in claim **1** wherein a filter system is located intermediate said main unit inlet port and said main unit exhaust port.

5. A portable airborne contamination control system as claimed in claim **1** wherein said exhaust port is adapted to include an exhaust duct mounting means, said exhaust duct mounting means having an elongated exhaust duct mounted thereon.

6. A portable airborne contamination control system as claimed in claim **5** wherein said elongated exhaust duct has a proximal end and a distal end, said proximal end mounted on said exhaust duct mounting means, said distal end being placed at an appropriate location away from said main unit permitting the suctioned air, overspray and errant particles to be conveyed away from said main unit.

7. A portable airborne contamination control system as claimed in claim **1** wherein said remote unit is adapted to be rolled on wheels.

* * * * *

Exhibit 12

US006983757B1

(12) **United States Patent**
Becker et al.

(10) **Patent No.: US 6,983,757 B1**
(45) **Date of Patent: Jan. 10, 2006**

(54) **PRESSURE DIFFERENTIAL DISTRIBUTION SYSTEM**

(75) Inventors: **Brian E. Becker**, Littleton, CO (US); **Matthew L. Becker**, Littleton, CO (US); **Carl D. Becker**, Evergreen, CO (US); **Ryan M. Becker**, Littleton, CO (US)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 251 days.

(21) Appl. No.: **10/110,646**

(22) PCT Filed: **Aug. 24, 2000**

(86) PCT No.: **PCT/US00/23269**

§ 371 (c)(1), (2), (4) Date: **Jul. 11, 2002**

(87) PCT Pub. No.: **WO01/27582**

PCT Pub. Date: **Apr. 19, 2001**

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(51) **Int. Cl.**
B67D 5/08 (2006.01)

(52) **U.S. Cl.** **137/14**; 137/565.16; 137/565.23; 138/107; 138/121; 454/63; 454/65

(58) **Field of Classification Search** 137/355.16, 137/565.23, 14; 138/107, 121; 454/63, 454/65
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,115,898 A		12/1963	Rothermel	138/122
3,200,765 A		8/1965	Ambli	104/52
3,911,944 A		10/1975	Hukuba et al.	137/355.2
4,009,734 A		3/1977	Sullivan	138/125
4,086,847 A		5/1978	Overmeyer	98/115 M
4,231,595 A	*	11/1980	Knutsen	285/38
4,343,420 A		8/1982	Scott	226/49
4,903,911 A		2/1990	Sepka	242/86
5,023,959 A	*	6/1991	Mercer	4/321
5,092,228 A	*	3/1992	Pfeiffer et al.	454/63
5,096,230 A		3/1992	Pausch et al.	285/9.1
5,119,843 A		6/1992	Keenan	137/355.23
5,156,349 A		10/1992	Wilson et al.	242/47.5
5,162,017 A		11/1992	Nordin	454/63

(Continued)

FOREIGN PATENT DOCUMENTS

GB WO 03/02494 A1 * 3/2003

(Continued)

OTHER PUBLICATIONS

Aero-Motive Company, Balancer Series 10F, 15F, 10FLR & 15 FLR Service Manual, May 1997, pp. 1-2.

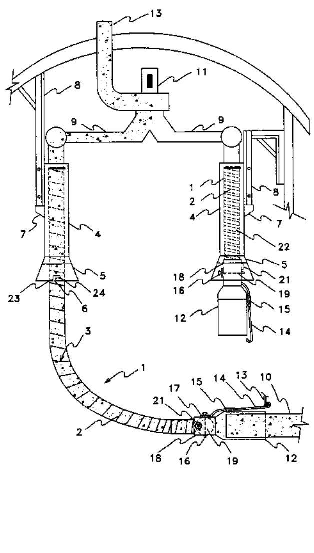
(Continued)

Primary Examiner—A. Michael Chambers
(74) *Attorney, Agent, or Firm*—Santangelo Law Offices, P.C.

(57) **ABSTRACT**

An pressure differential distribution system which offers an pressure differential reaction element **(1)** made of a comfortable, flexible pressure differential interface **(2)** that is attached to a support element **(3)**, which in conjunction with a difference in pressure between the interior volume of the differential reaction element **(1)** can conform to various extended or reduced conformers. The flexible pressure differential interface **(2)** may retract within an enclosure**(4)**. An emission removal adaptor **(12)** or terminal interface **(23)** may be coupled to a substance source **(10)** to capture or move substances on a pressure differential from a first zone to a second zone.

60 Claims, 15 Drawing Sheets



U.S. PATENT DOCUMENTS

5,224,739	A	7/1993	Sauter	285/41
5,362,273	A	11/1994	Pfeiffer, Jr. et al.	454/63
5,402,551	A	4/1995	Workhoven et al.	15/315
5,453,048	A	9/1995	Zima et al.	454/63
5,470,176	A *	11/1995	Corcoran et al.	404/72
5,482,089	A	1/1996	Weber et al.	138/122
5,536,206	A *	7/1996	Bodmer et al.	454/65
5,607,107	A	3/1997	Grieve, Jr.	239/195
5,679,072	A	10/1997	Brodin et al.	454/63
5,738,148	A *	4/1998	Coral et al.	138/120
5,791,980	A	8/1998	Kramer, Jr.	454/64
6,012,978	A	1/2000	Svensson et al.	454/63
6,139,422	A *	10/2000	Blaschke	454/63
6,607,009	B2 *	8/2003	Schoellhorn et al.	137/899

FOREIGN PATENT DOCUMENTS

WO	WO 01/27582	4/2001

OTHER PUBLICATIONS

Ammerman, Inc., Underfloor Automative Exhaust Systems, Nos. 400, 601, 700, 1000-5, and 1000-6, p. 2.
Banzai, Exhaust Hose Reels, Cover Picture; Nederman, Inc., Spring-Loaded Exhaust Hose Reels, p. 2.
Carmon Products, Inc., Car-mon Tubing Storage Reel Drawing No. 85-R1, p. 1.
Carmon Products, Inc., Carmon Rotoboom, RotoBoom, Drawing No. 79D5; Tykron, Inc., Swing Arm with Hose and Balancer, p. 1.
Carmon Products, Inc., Carmon Tube Assemblies, Drawing No. 86-D1, p. 1.
Carmon Products, Inc., Sales Brochure, Carmon Tube Assemblies, Drawing No. 86-D1, p. 1.
Carmon Products, Inc., Carmon RotoBoom, Rotoboom Drawing No. 79D5; and Ammerman, Inc., Underfloor Automotive Exhaust Systems, p. 2.
Carmon Products, Inc., Carmon Overhead Disappearing Exhaust System, Drawing No. 86-D3; Cesco-Advanced Air, Flexible Tubing, Drawing No. F558-305A 11/25, p. 1, (1980).
Cesco-Advanced Air, Flexible Tubing, Drawing F558-305A 11/25, p. (1980).
Cesco-Advanced Air, Sales Brochure, Underfloor Disappearing with Vitrified Clay Pipe, Drawing No. F551-305A378, p. 1 (1978).
Euro-Roller, Cover Picture; Fumex, Hose Reel For Exhaust Extraction, Hose Reel, Part No. SR 10, p. 1.
Harvey Corp., Carbon Moxoide Exhaust Removal System, Harvey Components and Accessories, p. 2.
Harvey Corp., Carbon Monoxide Removal System, Harvey Components and Accessories, p. 2.
Harvey Inc., Carbon Monoxide Exhaust Removal System, Harvey Overhead Exhaust System, p. 6.
Harvey Inc., Carbon Monoxide Exhaust Removal System, Harvey Hose and Tubing, Part H-40-20-AF or H-50-12- AF, p. 9.
Monoxivent Systems Inc., Technical Information Sheet, Vehicle Exhaust Damper, Series TCA, p. 3-A.
Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1; Nederman Inc., Nozzles For Vehicle Exhaust Extraction, Nozzles for Trucks and Other Commercial Vehicles, p. 2.
Monoxivent Systems Inc., Technical Information, Vehicle Exhaust Damper, Series TCA, p. 3-A.
Monoxivent Systems Inc., Technical Information, Monoxivent Overhead Systems, p. 4.
Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1 Nederman Inc., Overhead Exhaust Extractor, Nederman Simple Exhaust Extractors, p. 2.
Monoxivent Systems Inc., Monoxivent Exhaust Elimination Systems, Hose Assembly Order Form, p. 3.
Monoxivent Systems Inc., Monoxivent Overhead Systems, p. 4.
Nederman Inc., Overhead Exhaust Extractor, Single and Double Extractor Fans, Drawing No. 13-2, p. 2, May 1997.
Nederman Inc., Overhead Exhaust Extractor, Nederman Simple Exhaust Extractors, p. 2, May 1997.
Nederman Inc., Nozzles For Vehicle Exhaust Extraction, Nozzles for Trucks and Other Commercial Vehicles, p. 2.
U.S. Appl. No. 60/261,077, "Self-Positioning Differential Pressure Distribution System", filed on Jan. 11, 2001.
U.S. Appl. No. 60/159,265, "Self-Retracting Emission Removal System", filed Oct. 13, 1999.
U.S. Appl. No. 60/261,469, "Tensioned Differential Pressure Distribution Interface Securement System", filed Jan. 12, 2001.
Sacatec, Inc., Hosereel For Exhaust Extraction, Cover, p. 1.
Sacatec, Inc., Garage Exhaust—Ventilation Systems, Drawing No. SA0286-1, p. 1.
Technical Manual, Exhaust-O-Vent, p. 2 (1985).
Tykron, Inc., Swing Arm with Hose and Balancer, p. 1.
Tykron, Inc., Vehicle Exhaust Gas Control for Removal of Exhaust Fumes, p. 1.
Aero-Motive Company, Balancer Series 10F, 15F, 10FLR & 15 FLR Service Manual, May 1997, pp. 1-2, not later than Oct. 13, 1999.
Ammerman, Inc., Underfloor Automotive Exhaust Systems, Nos. 400, 601, 700, 1000-5, and 1000-6, p. 2, not later than Oct. 13, 1999.
Banzai, Exhaust Hose Reels, Cover Picture; Nederman, Inc., Spring-Loaded Exhaust Hose Reels, p. 2, not later than Oct. 13, 1999.
Carmon Products, Inc., Car-mon Tubing Storage Reel Drawing No. 85-R1, p. 1, not later than Oct. 13, 1999.
Carmon Products, Inc., Carmon Rotoboom, RotoBoom, Drawing No. 79D5; Tykron, Inc., Swing Arm with Hose and Balancer, p. 1, not later than Oct. 13, 1999.
Carmon Products, Inc., Carmon Tube Assemblies, Drawing No. 86-D1, p. 1, not later than Oct. 13, 1999.
Carmon Products, Inc., Sales Brochure, Carmon Tube Assemblies, Drawing No. 86-D1, p. 1, not later than Oct. 13, 1999.
Carmon Products, Inc., Carmon RotoBoom, Rotoboom Drawing No. 79D5; and Ammerman, Inc., Underfloor Automotive Exhaust Systems, p. 2, not later than Oct. 13, 1999.
Carmon Products, Inc., Carmon Overhead Disappearing Exhaust System, Drawing No. 86-D3; Cesco-Advanced Air, Flexible Tubing, Drawing No. F558-305A 11/25, p. 1, (1980).
Cesco-Advanced Air, Flexible Tubing, Drawing F558-305A 11/25, p. 1 (1980).
Cesco-Advanced Air, Sales Brochure, Underfloor Disappearing with Vitrified Clay Pipe, Drawing No. F551-305A378, p. 1 (1978).
Euro-Roller, Cover Picture; Fumex, Hose Reel For Exhaust Extraction, Hose Reel, Part No. SR 10, p. 1, not later than Oct. 13, 1999.
Harvey Corp., Carbon Moxoide Exhaust Removal System, Harvey Components and Accessories, p. 2, not later than Oct. 13, 1999.

Harvey Corp., Carbon Monoxide Removal System, Harvey Components and Accessories, p. 2, not later than Oct. 13, 1999.
Harvey Inc., Carbon Monoxide Exhaust Removal System, Harvey Overhead Exhaust System, p. 6, not later than Oct. 13, 1999.
Harvey Inc., Carbon Monoxide Exhaust Removal System, Harvey Hose and Tubing, Part H-40-20-AF or H-50-12- AF, p. 9, not later than Oct. 13, 1999.
Monoxivent Systems Inc., Technical Information Sheet, Vehicle Exhaust Damper, Series TCA, p. 3-A, not later than Oct. 13, 1999.
Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1; Nederman Inc., Nozzles For Vehicle Exhaust Extraction, Nozzles for Trucks and Other Commercial Vehicles, p. 2, not later than oct. 13, 1999.
Monoxivent Systems Inc., Technical Information, Vehicle Exhaust Damper, Series TCA, p. 3-A; not later than Oct. 13, 1999.
Monoxivent Systems Inc., Technical Information, Monoxivent Overhead Systems, p. 4; not later than Oct. 13, 1999.
Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1 Nederman Inc., Overhead Exhaust Extractor, Nederman Simple Exhaust Extractors, p. 2, not later than Oct. 13, 1999.
Monoxivent Systems Inc., Monoxivent Exhaust Elimination Systems, Hose Assembly Order Form, p. 3, not later than Oct. 13, 1999.
Monoxivent Systems Inc., Monoxivent Overhead Systems, p. 4, not later than Oct. 13, 1999.
Nederman Inc., Overhead Exhaust Extractor, Single and Double Extractor Fans, Drawing No. 13-2, p. 2, May 1997.
Nederman Inc., Overhead Exhaust Extractor, Nederman Simple Exhaust Extractors, p. 2, May 1997.
Nederman Inc., Nozzles For Vehicle Exhaust Extraction, Nozzles for Trucks and Other Commercial Vehicles, p. 2, not later than Oct. 13, 1999.
U.S. Appl. No. 60/261,077, “Self-Positioning Differential Pressure Distribution System”, filed on Jan. 11, 2001.
U.S. Appl. No. 60/159,265, “Self-Retracting Emission Removal System”, filed Oct. 13, 1999.
U.S. Appl. No. 60/261,469, “Tensioned Differential Pressure Distribution Interface Securement System”, filed Jan. 12, 2001.
Tykron, Inc., Vehicle Exhaust Gas Control for Removal of Exhaust Fumes, p. 1, not later than Oct. 13, 1999.

* cited by examiner

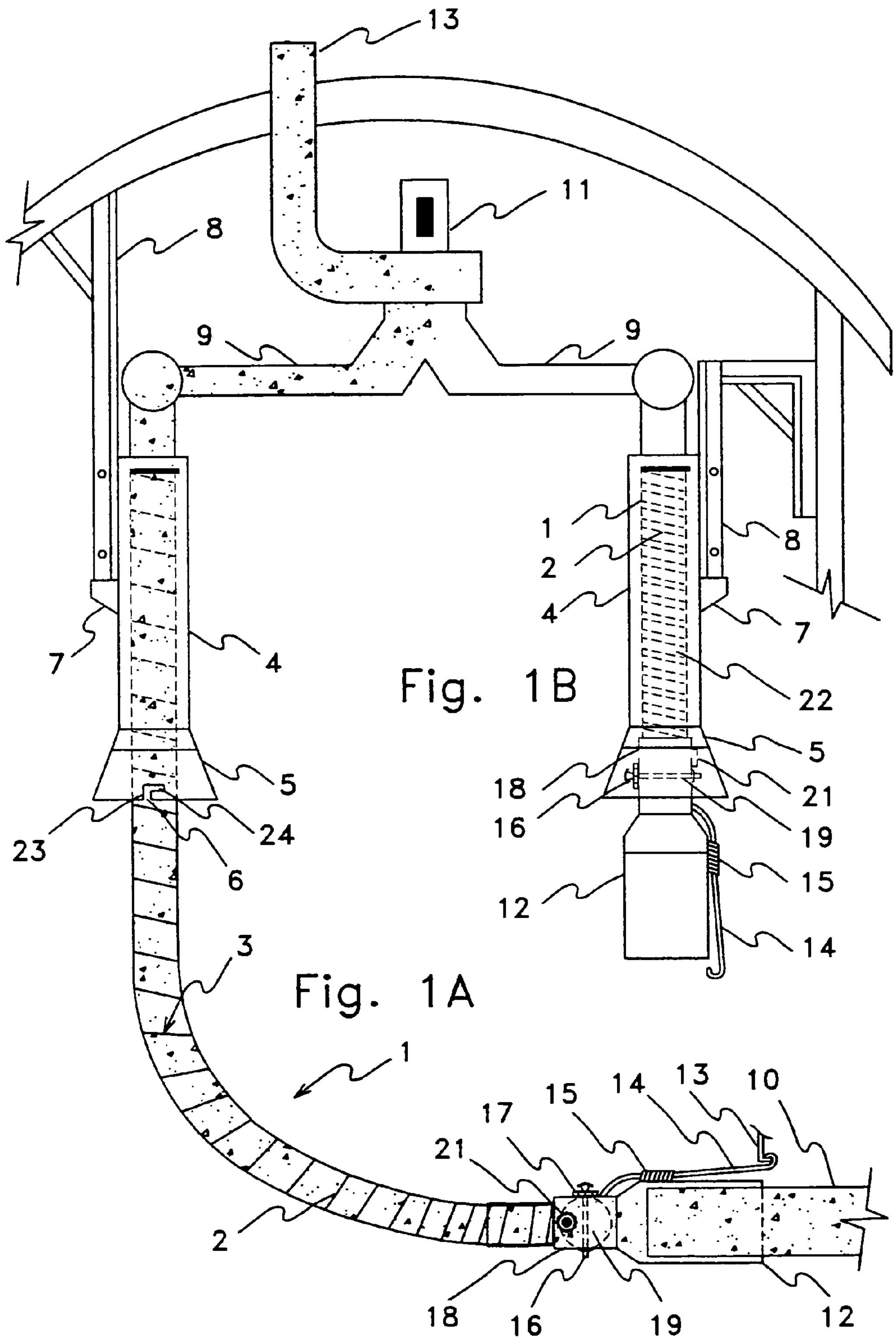

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Fig. 1B

Fig. 1A

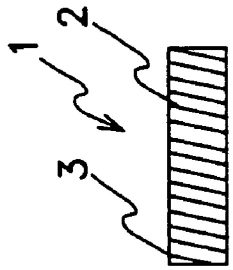


Fig. 2B

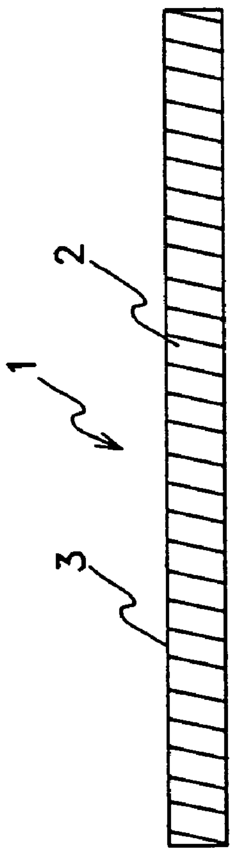


Fig. 2A

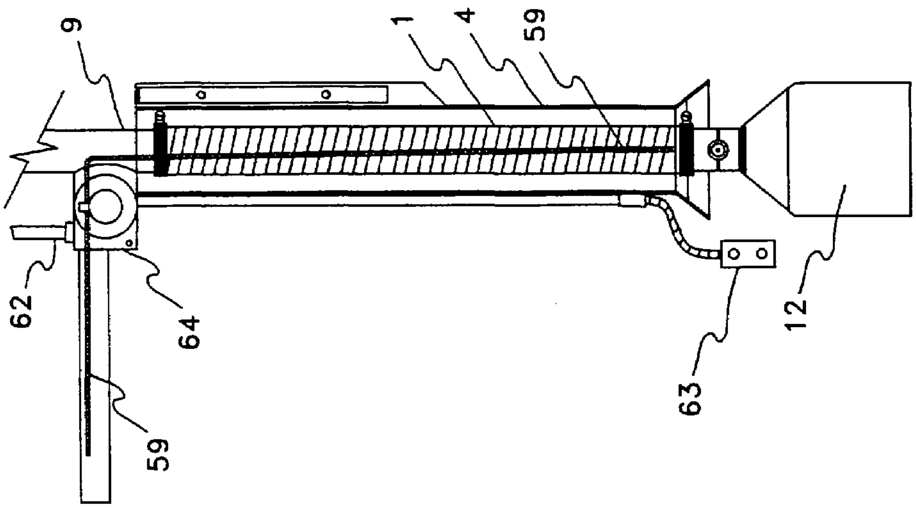


Fig. 3C

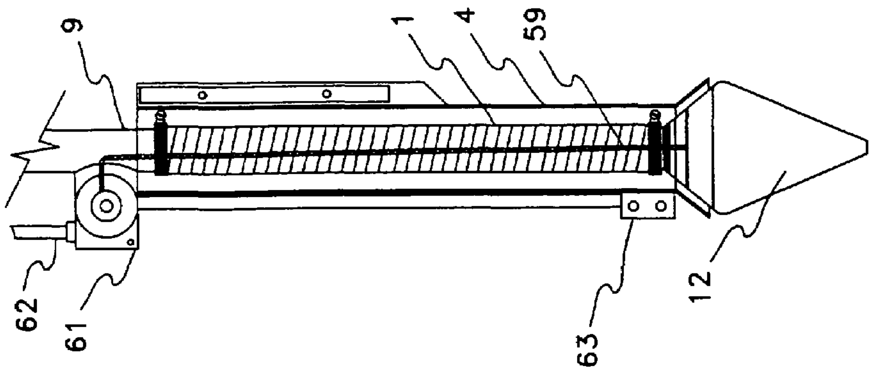


Fig. 3B

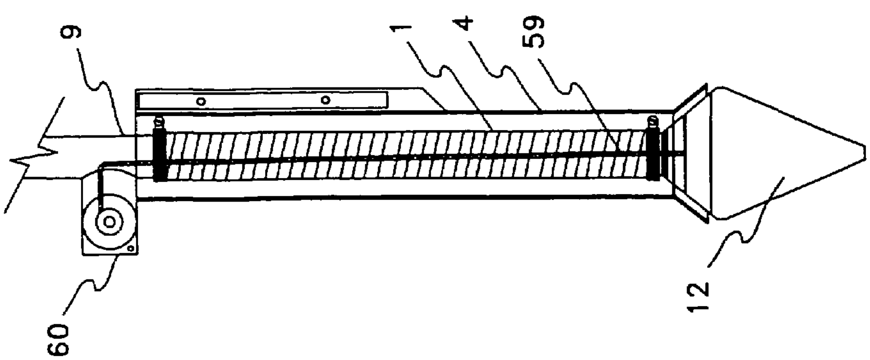


Fig. 3A

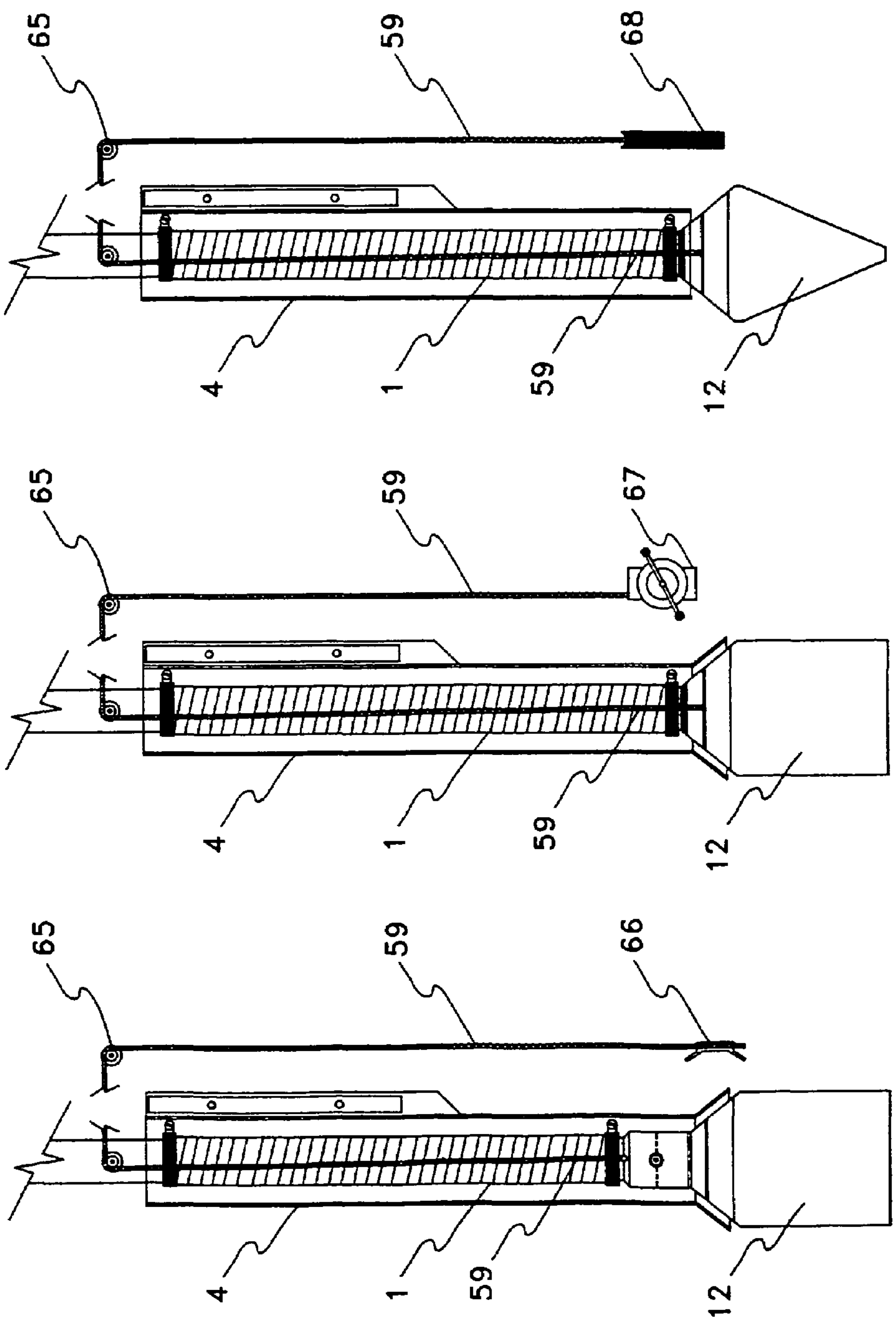


Fig. 4C

Fig. 4B

Fig. 4A

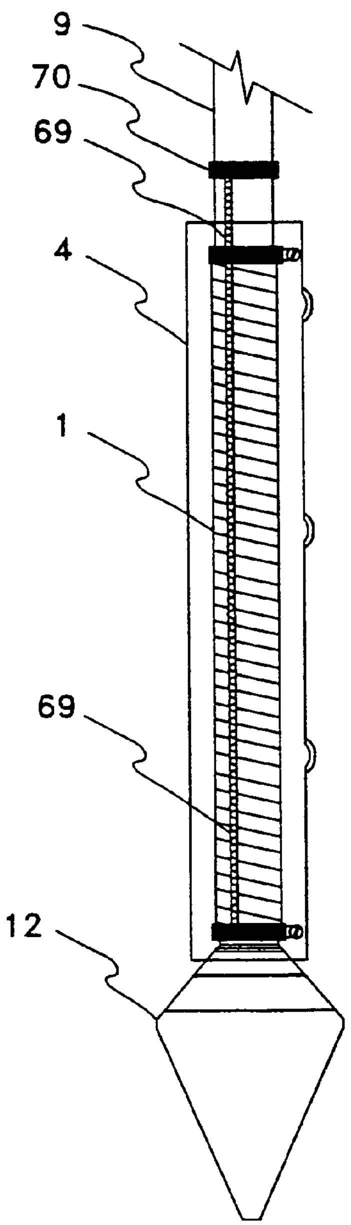


Fig. 5A

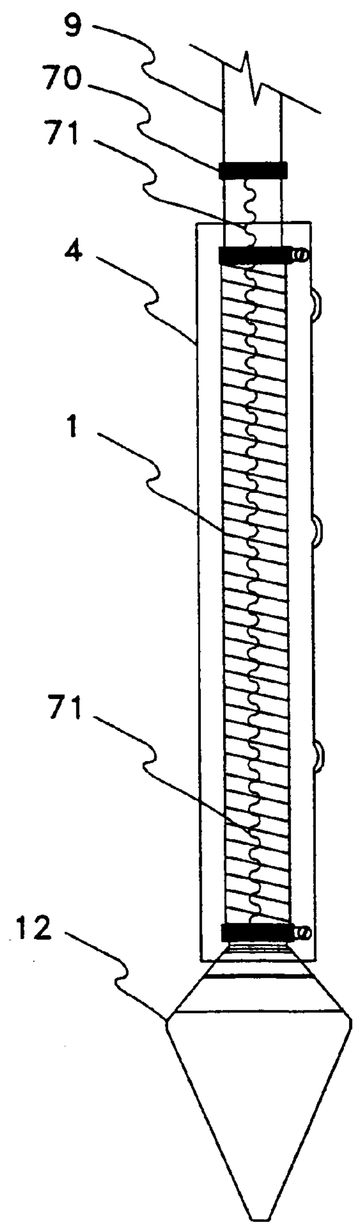
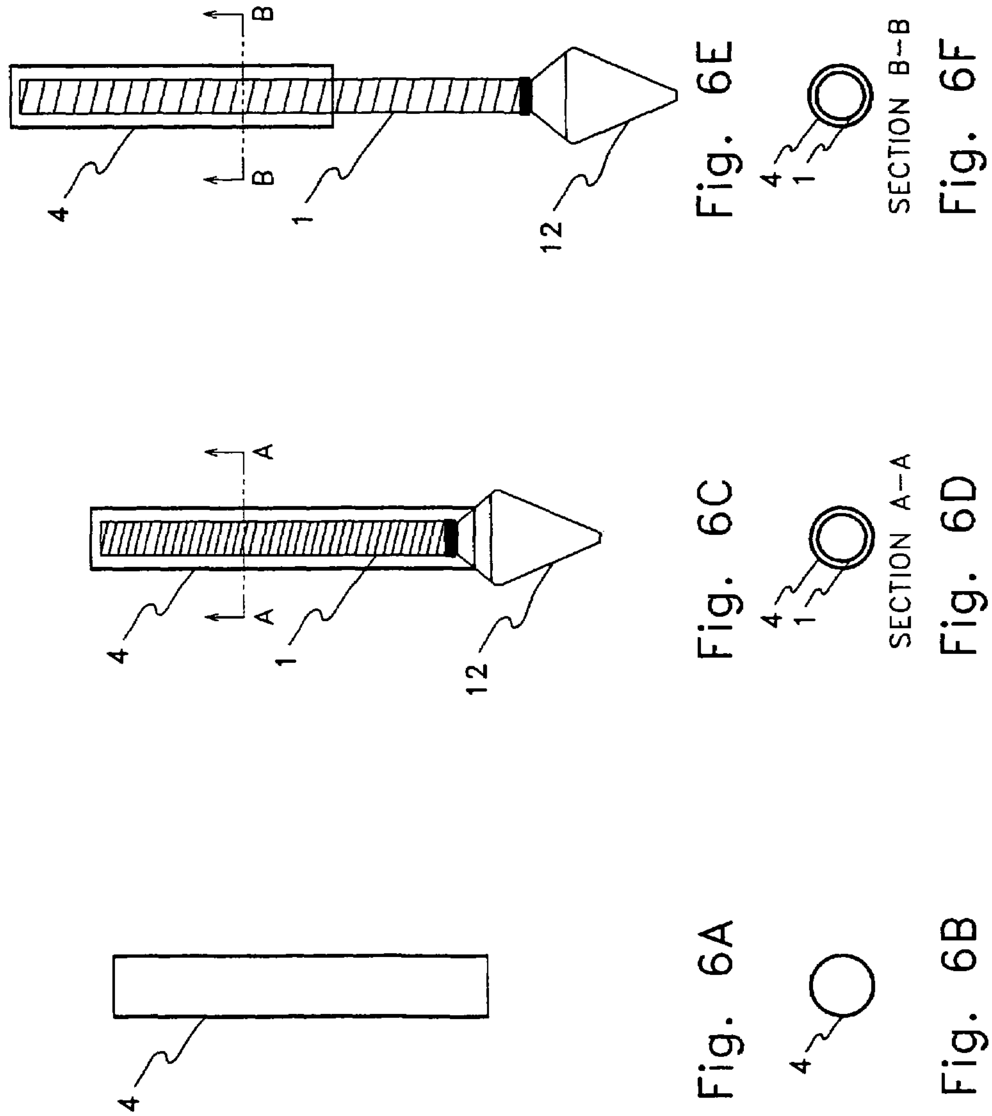


Fig. 5B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12
Fig. 6E
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SECTION B–B
Fig. 6F
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Fig. 6C
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SECTION A–A
Fig. 6D
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Fig. 6A
4
Fig. 6B

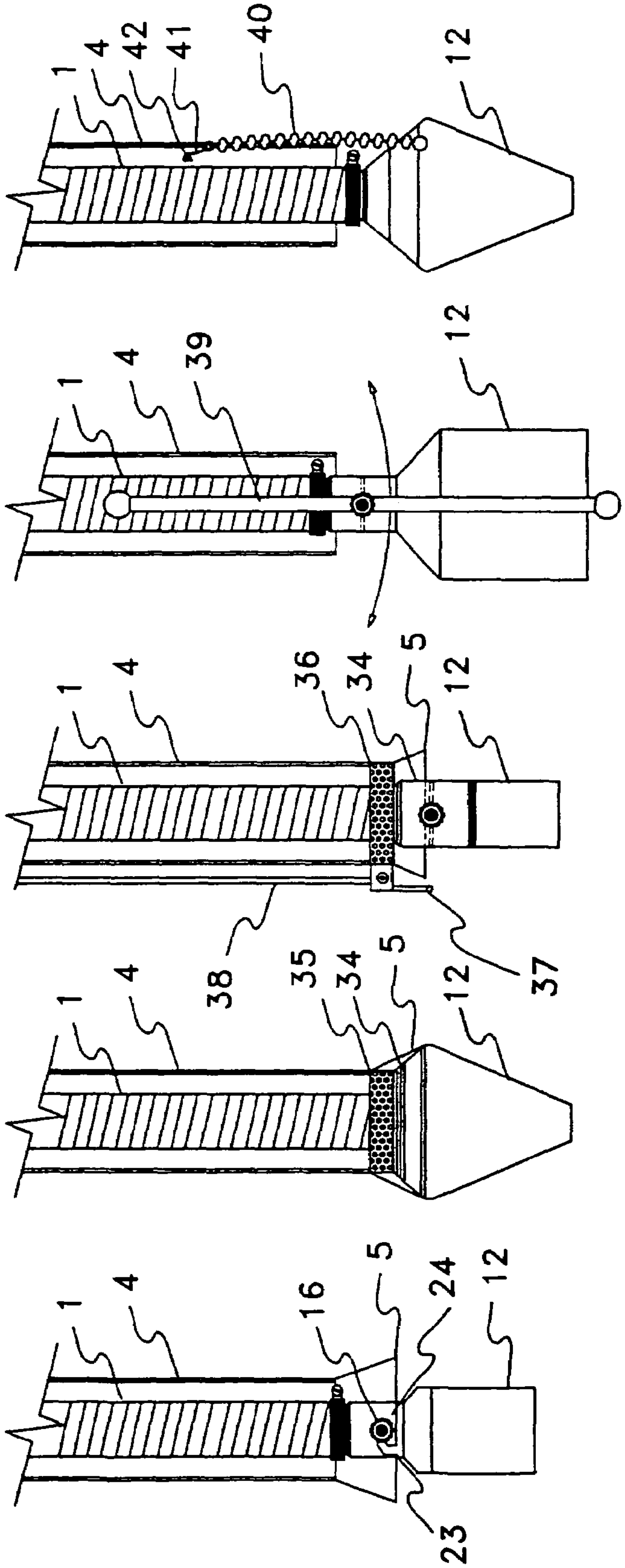

Fig. 7E

Fig. 7D

Fig. 7C

Fig. 7B

Fig. 7A

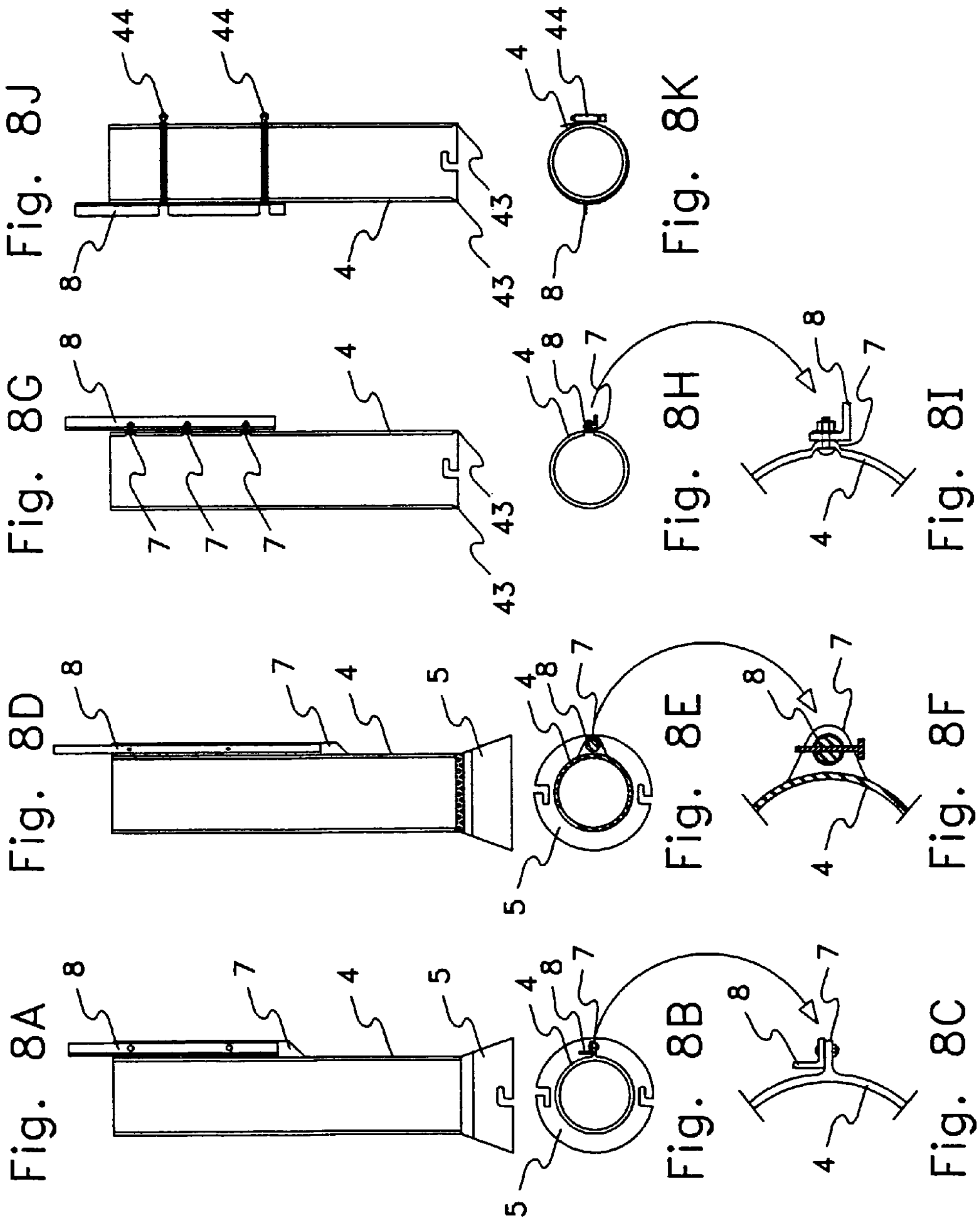

Fig. 8A Fig. 8B Fig. 8C Fig. 8D Fig. 8E Fig. 8F Fig. 8G Fig. 8H Fig. 8I Fig. 8J Fig. 8K

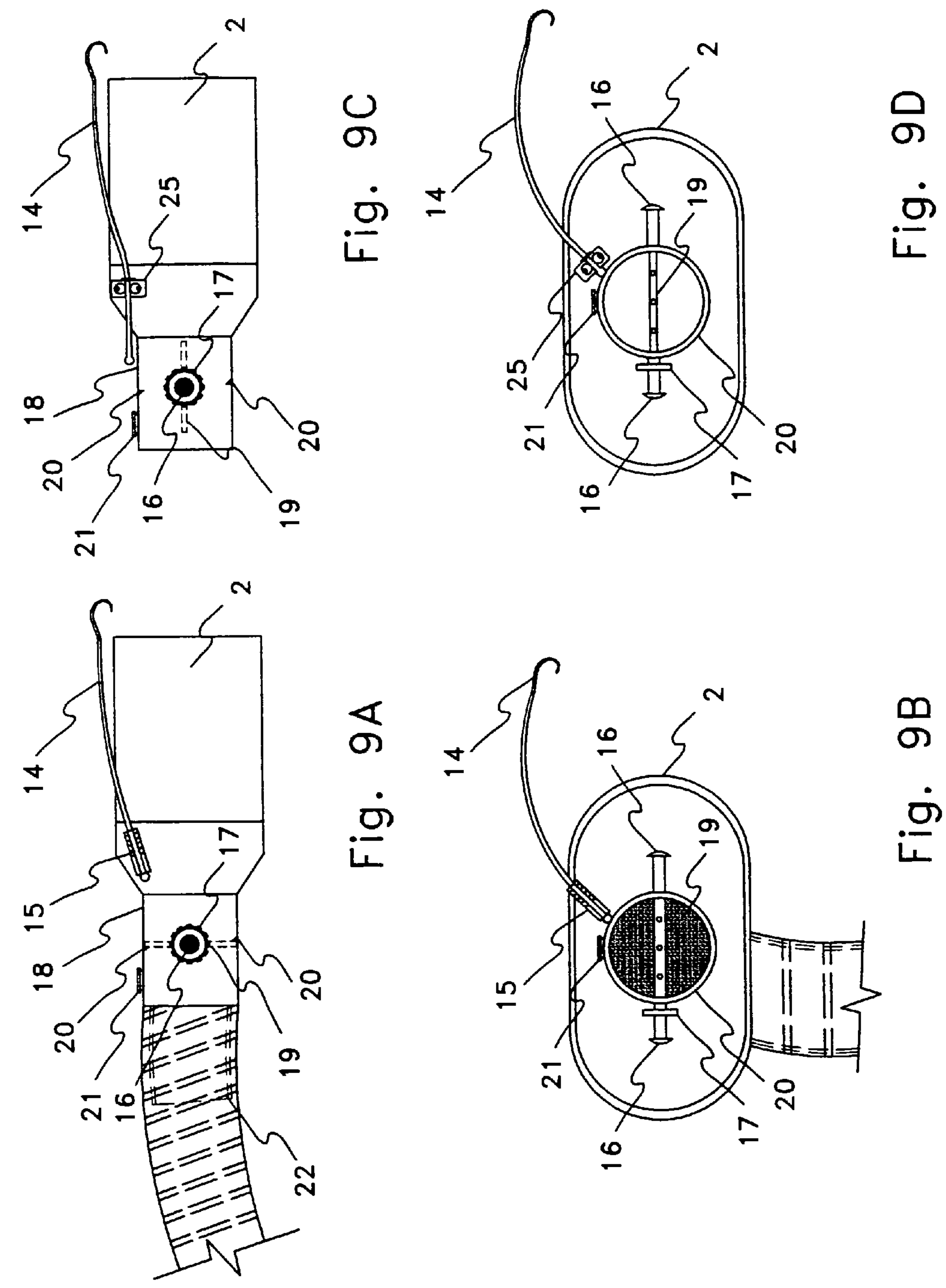

Fig. 9C

Fig. 9D

Fig. 9A

Fig. 9B

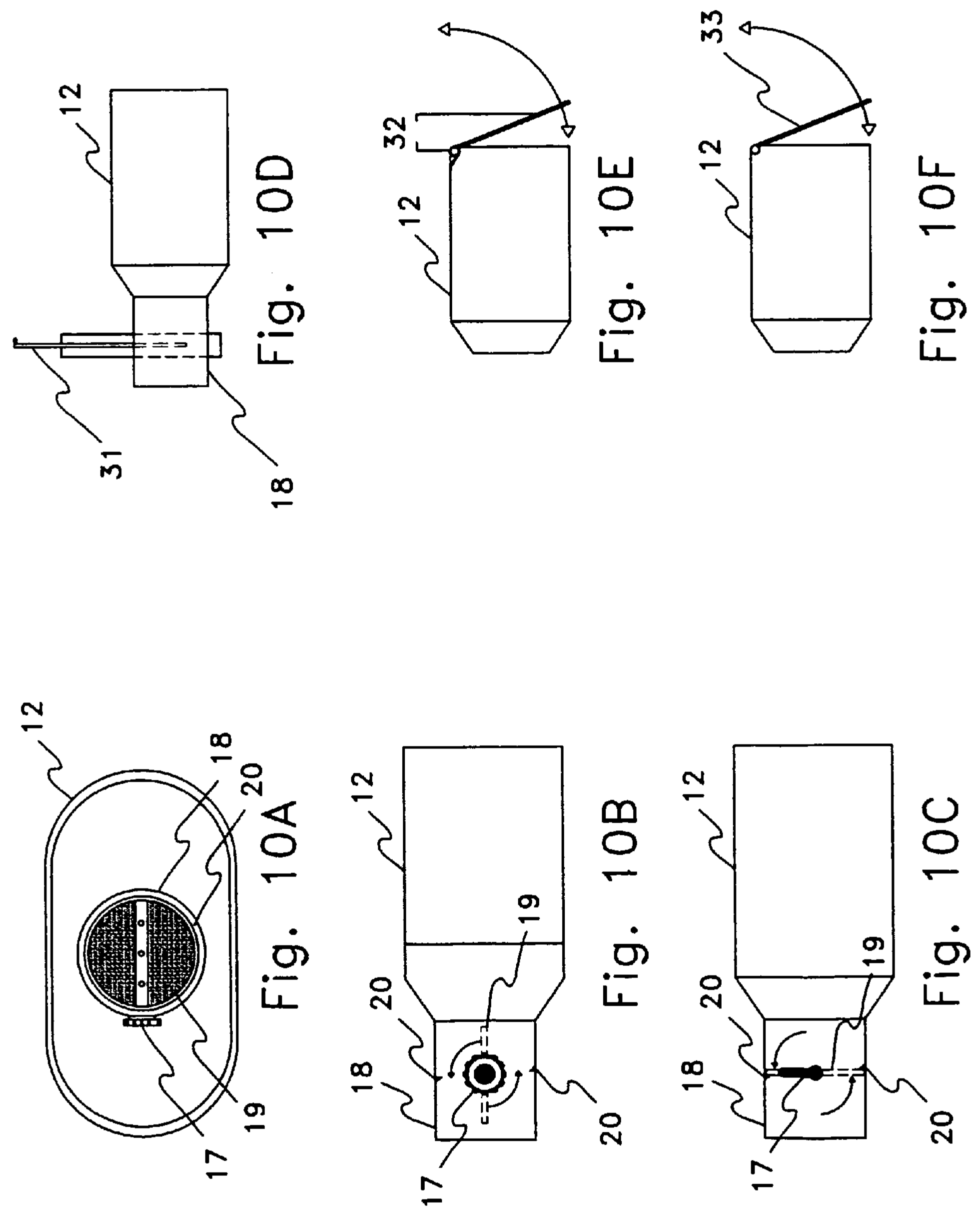

Fig. 10A

Fig. 10B

Fig. 10C

Fig. 10D

Fig. 10E

Fig. 10F

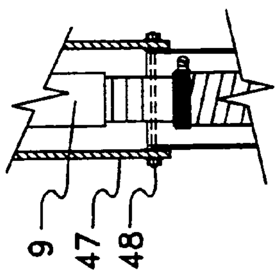

Fig. 11C

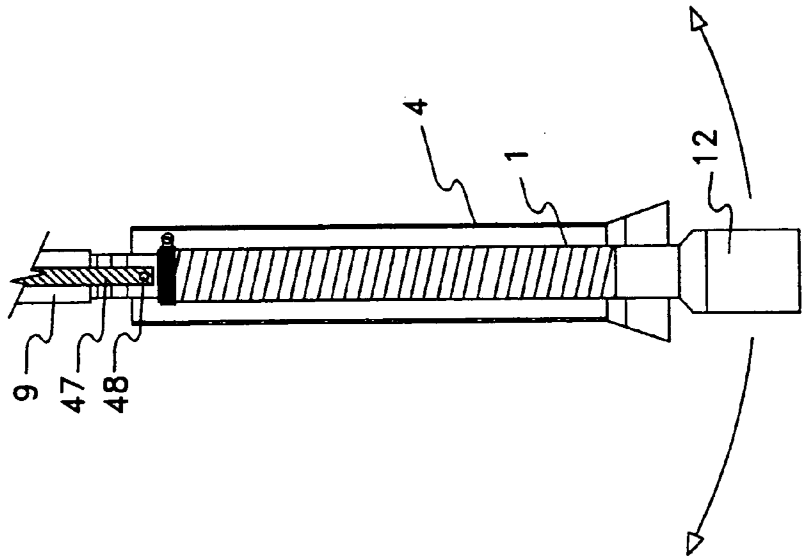

Fig. 11B

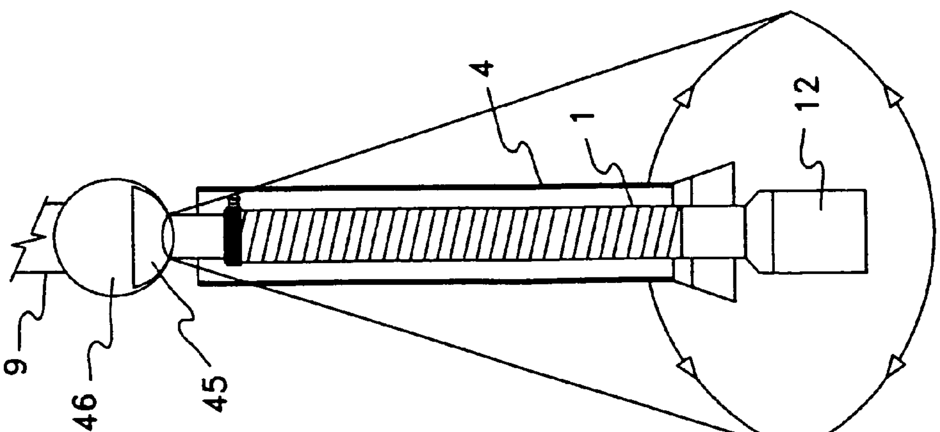

Fig. 11A

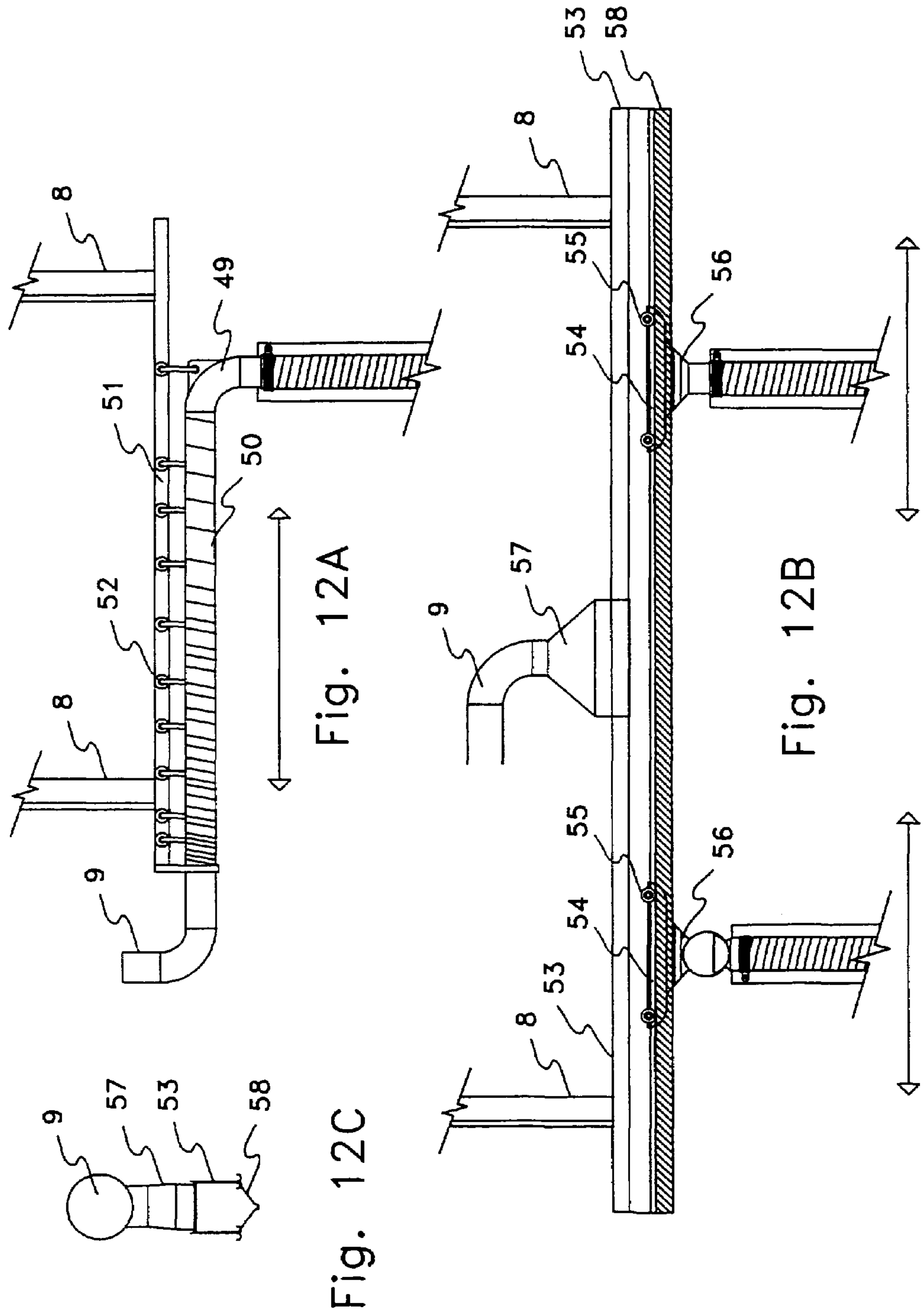

Fig. 12A

Fig. 12B

Fig. 12C

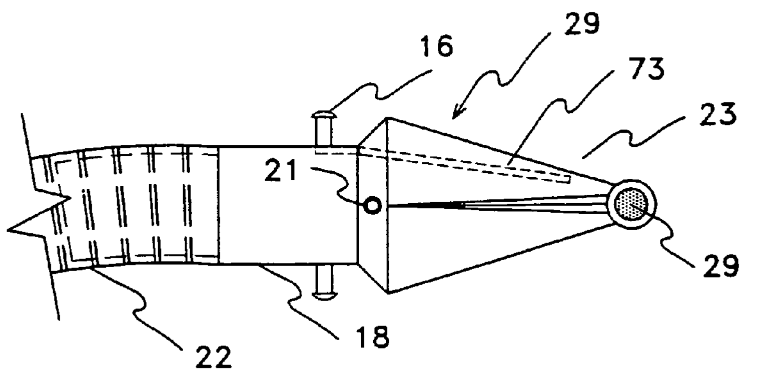

Fig. 13A

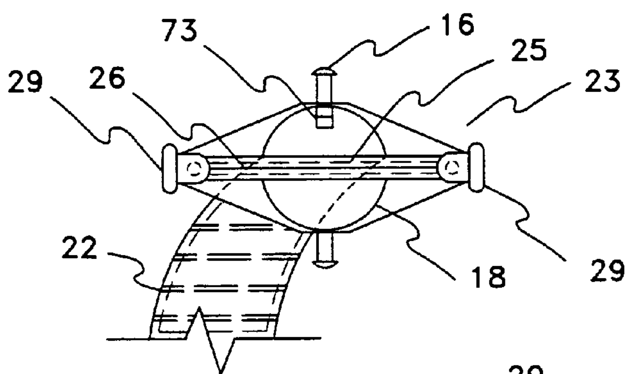

Fig. 13B

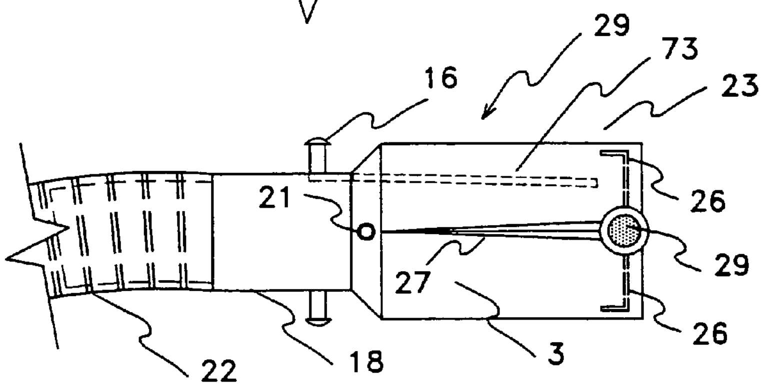

Fig. 13C

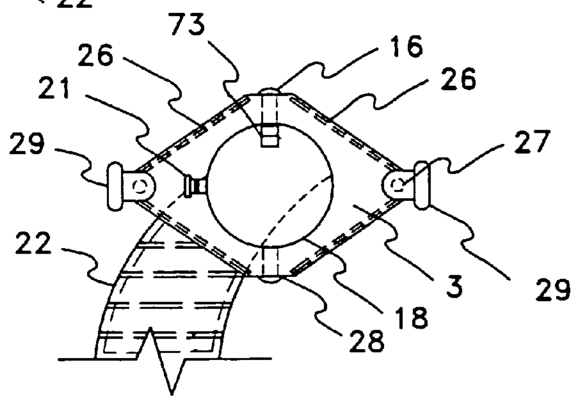

Fig. 13D

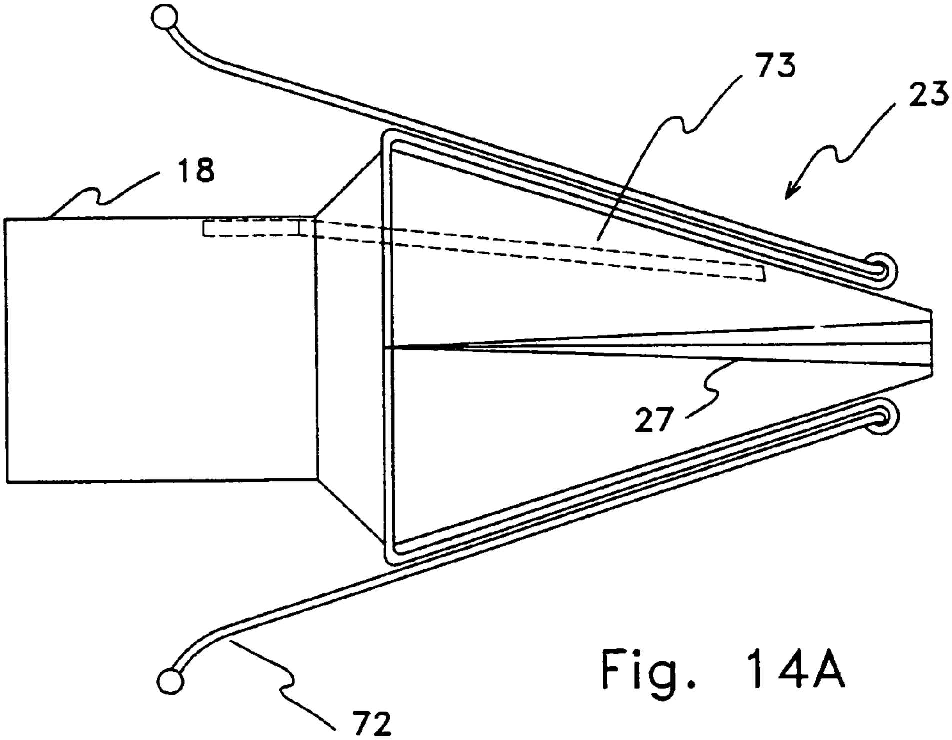

Fig. 14A

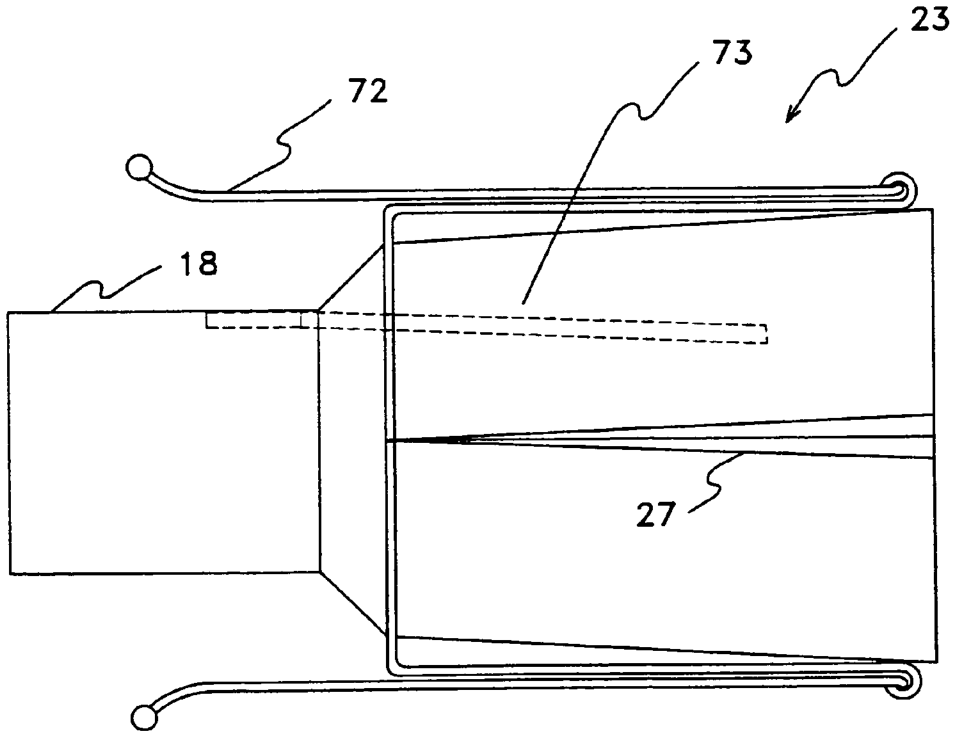

Fig. 14B

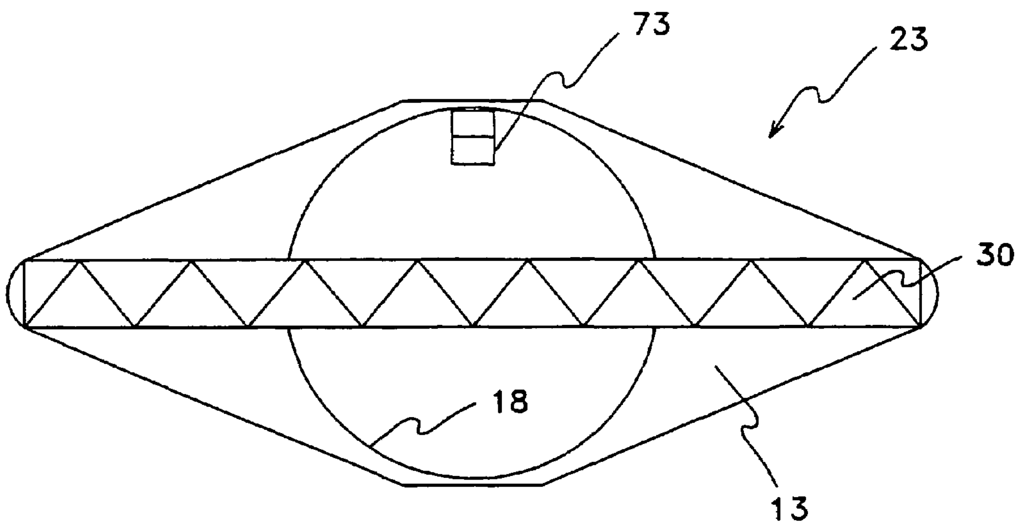

Fig. 15A

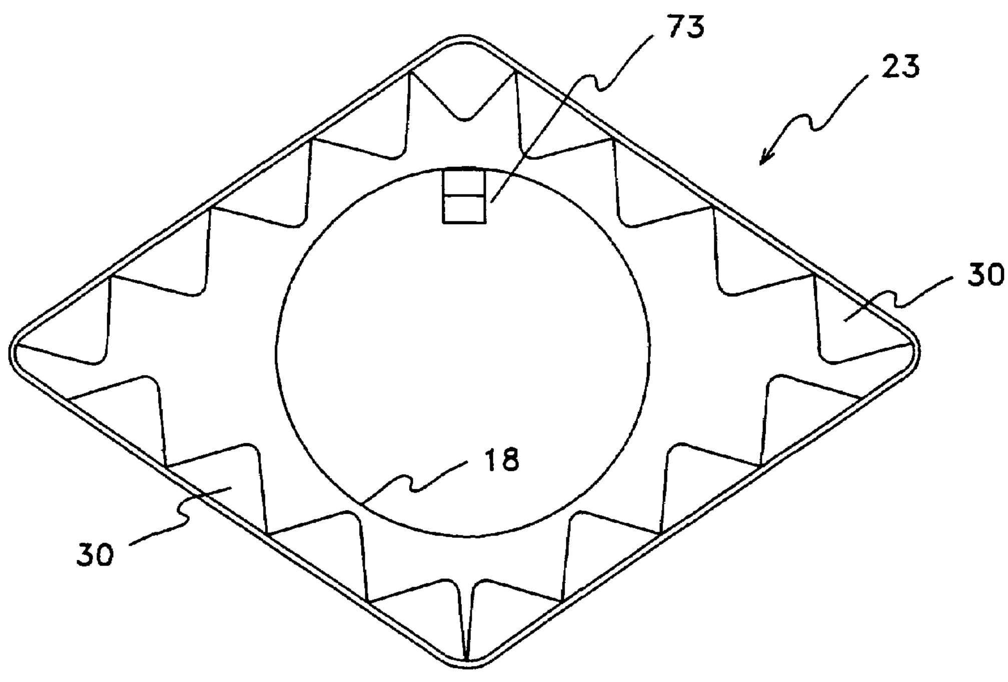

Fig. 15B

PRESSURE DIFFERENTIAL DISTRIBUTION SYSTEM

TECHNICAL FIELD

Generally, the invention relates to apparatus and methods for distributing a pressure differential between an interior volume and an exterior volume. Specifically, a pressure differential distribution system for capturing or transporting substances from a first zone to a second zone.

BACKGROUND

Movement of objects or substances on a pressure gradient along at least one path from a first zone to a second zone encompasses technology such as pneumatic tube systems, vacuum cleaning systems, emission removal systems, ventilation systems, fluid distribution systems, or the like.

Often, the use of these systems or the substances transported by them is regulated by law. Specifically, with respect to emission removal from indoor facilities, the need to remove unwanted, unhealthy or potentially lethal emissions from facilities is regulated by various federal, state, and local laws. For example, the 1996 International Mechanical Code, Section 502.11, stipulates that " . . . areas in which stationary motor vehicles are operated shall be provided with a source capture system that connects directly to the motor vehicle exhaust systems." *International Mechanical Code* (1996), hereby incorporated by reference. The presence of exhaust emissions may be detrimental to the health and well-being of persons who work in facilities in which such emissions are present. Not only may these emissions be harmful to the long-term health or well-being of persons inside the facility, but these emissions are also unpleasant or repellent to the senses. If not captured, these emissions may also attach themselves to the bodies or clothing of persons inside the facility. Furthermore, over time, the emissions may also stain the interior surfaces of the facility, causing the building to become an unattractive, malodorous, or unpleasant work environment.

Because of the convenience, health, safety, or legal concerns which can be addressed by pressure differential distribution systems there is a large commercial market for these systems. As such, numerous products have been introduced into the marketplace over the years. These various products or methods offer differing degrees of effectiveness in fulfilling the entire spectrum of substance movement, statutory, safety, or consumer requirements. However, even though a variety of devices have been introduced into the marketplace, substantial problems with existing devices remain unresolved.

A significant problem with existing pressure differential distribution devices may be that they are large or take up a lot of space. Since space in any facility is finite, it follows that different mechanical, structural, or electrical items may compete for space. The larger the pressure differential distribution device the less space that can be reserved for other uses. The large size of current devices also presents a problem for installers. If installed prior to other mechanical or electrical fixtures, a large pressure differential distribution device may present an obstacle to the installation of subsequent mechanical or electrical fixtures; on the other hand, if the emission extraction system is to be installed after other fixtures are in place, a large system may not fit as easily as a smaller one. Additionally, large devices increase shipping costs inherent in transporting a heavier item. Examples of existing large pressure differential distribution devices are

disclosed by Harvey Inc., *Carbon Monoxide Exhaust Removal System*, Harvey Overhead Exhaust System, p. 6; Tykron, Inc., Vehicle Exhaust Gas Control, p. 1; Euro-Roller, Cover Picture; Fumex, *Hosereel For Exhaust Extraction*, Part No. SR 10, p. 1; Banzai, *Exhaust Hose Reels*, Exhaust Hose Reels, Cover Picture; Nederman, Inc., Spring-Loaded Exhaust Hose Reels, p. 2; Carmon Products, Inc., Car-mon Tubing Storage Reel Drawing No. 85-R1, p. 1, each of which is hereby incorporated by reference. Similarly, other types of large pressure differential distribution devices such as boom arms may furnish the consumer with the ability to swing the pressure differential distribution device along an arc, providing some mobility, however, these devices generate an operating boundary within which other objects or equipment may not typically be used. Examples of this type of large device are disclosed by Carmon Products, Inc., *Carmon Rotoboom*, RotoBoom, Drawing No. 79D5; Tykron, Inc., Swing Arm with Hose and Balancer, p. 1, each of which is hereby incorporated by reference. See also the devices disclosed by U.S. Pat. Nos. 4,086,847; 5,402,551; 5,119,843; 5,362,273; and 6,012,978, each of which is hereby incorporated by reference, as examples of large devices.

Another significant problem with existing pressure differential distribution devices may be that the various components of the device, even when in the stored position, are visually or mechanically exposed. With respect to the mechanical exposure of the device, having the components open to various types of physical mistreatment (for example, being inadvertently hit or run into) or to other environmental abuses (for example, chemical spills or spatters, or abrasives from various procedures) may lead to premature wear of the components. With respect to the visual appearance, not only may the components of the device lack pleasing aesthetics for the consumer who may purchase the device (or not if the appearance is too awkward), but also to the public to which the device may connote an unattractive image. See for example, exposed components of devices disclosed by Harvey Inc., *Carbon Monoxide Exhaust Removal System*, Harvey Overhead Exhaust System, p. 6; Tykron, Inc., Vehicle Exhaust Gas Control for Removal of Exhaust Fumes, p. 1; Euro-Roller, Cover Picture; Fumex, *Hose Reel For Exhaust Extraction*, Hose Reel, Part No. SR 10, p. 1; Banzai, Exhaust Hose Reels, Cover Picture; Nederman, Inc., Spring-Loaded Exhaust Hose Reels, p. 2; Carmon Products, Inc., Carmon Tubing Storage Reel, Drawing No. 85-R1 p. 1, each of which is hereby incorporated by reference. See also, U.S. Pat. Nos. 5,119,843; 5,402,551; 6,012,978; 4,086,847; and 5,679,072, each of which is hereby incorporated by reference, as examples of devices having exposed components.

Another significant problem with existing pressure differential distribution devices may be that they utilize an exhaust hose that features a corrugated configuration. This corrugation greatly diminishes the pressure differential generator's or exhaust fan's capacity to draw substances or emissions through the corrugated hose. The corrugation creates resistance to gas flow, thereby requiring more powerful pressure differential generator. Unfortunately, as the power of the pressure differential generator increases, it becomes more expensive to purchase and to operate. Moreover, a more powerful pressure differential generator may produce a greater amount of noise, yet another irritant to those who are in close proximity to the system. Examples of corrugated hose are disclosure by Harvey Inc., *Carbon Monoxide Exhaust Removal System*, Harvey Hose and Tubing, Part H-40-20-AF or H-50-12-AF, p. 9; Cesco-Advanced Air, Flexible Tubing, Drawing F558-305A 11/25, p. 1

(1980); and Sacatec, Inc., *Garage Exhaust—Ventilation Systems*, Drawing No. SA0286-1, p. 1, each of which hereby incorporated by reference. See also U.S. Pat. Nos. 3,911,944; and 5,791,980, each of which is hereby incorporated by reference, as examples of corrugated configurations.

Another significant problem with existing pressure differential distribution devices may be that certain hose retraction methods pose risk of injury to persons. One type of device uses a spring-activated mechanism, often called a "balancer", for hoisting the hose or terminal adapter into a stored position. This method of retrieval may be disclosed, for example, by Tykron, Inc., Swing Arm with Hose and Balancer, p. 1, hereby incorporated by reference. If the hose is released prematurely by the operator, the hose or adapter may sling toward an unsuspecting fellow worker, or may cause damage to any object in its trajectory, due to the fact that the hoisting mechanism may be under high-torque spring tension. This hazard is particularly serious when the adapter is constructed of metal or has protruding elements. According to a disclosure by Aero-Motive Company, Balancer Series 10F, 15F, 10FLR & 15 FLR, pp. 1–2, hereby incorporated by reference, improper use of a balancer mechanism "could result in serious injury, death, or property damage". See also, U.S. Pat. No. 5,679,072, hereby incorporated by reference, as an example of a device having a "balancer" component.

Another significant problem with existing pressure differential distribution devices may be that they are difficult to operate. Often existing devices have unwieldy product-to-operator interfaces which can be frustrating or annoying to the operator. Many presently offered hoses or adapters, the components of the devices which are most frequently handled by the operator, are not designed to promote ease of use. For example, high temperature hose, utilized in most military and governmental vehicle maintenance shops, historically has been made of heavy stainless steel or galvanized tubing that may be cumbersome or difficult to maneuver. It is not uncommon for the operator, frustrated with the awkwardness or clumsiness of such hoses, to abandon their use even when abandonment may result in the waste of the financial resources invested in the pressure differential distribution device, or in the possibility of adverse health ramifications. Examples of such cumbersome, stainless steel tubing are disclosed by Monoxivent Systems Inc., *Monoxivent Exhaust Elimination Systems*, Hose Assembly Order Form, p. 3; Monoxivent Systems Inc., Monoxivent Overhead Systems, p. 4; Carmon Products, Inc., *Carmon Rotoboom*, RotoBoom, Drawing No. 79D5, p. 1, Carmon Products, Inc., Carmon Overhead Disappearing Exhaust System, Drawing No. 86-D3; Cesco-Advanced Air, Flexible Tubing, Drawing No. F558-305A 11/25, p. 1, (1980), each of which is hereby incorporated by reference.

Another significant problem with existing pressure differential distribution devices may be that they do not accommodate applications in which the emission extraction system must be mobile. Hose reels, for example, are often fastened to the walls, ceiling, or fixtures of a facility and can be completely immobile. Use of the system is often confined to a radius equal to the hose length. In-floor devices are completely immobile and, once again, the length of the exhaust hose may be the limit of the area in which an in-floor system may be used. See for example, Carmon Products, Inc., Cannon RotoBoom, Rotoboom Drawing No. 79D5; and Ammerman, Inc., *Underfloor Automotive Exhaust Systems*, p. 2, each of which is hereby incorporated by reference.

Another significant problem with existing pressure differential distribution devices may be that they must be mounted with great precision or with significant structural attachment considerations, due to the larger weight of the devices. Examples are disclosed by Monoxivent Systems Inc., *Technical Information*, Monoxivent Overhead Systems, p. 4; Nederman Inc., *Overhead Exhaust Extractor*, Single and Double Extractor Fans, Drawing No. 13-2, p. 2; and Tykron, Inc., Swing Arm with Hose and Balancer, p. 1, each of which is hereby incorporated by reference.

Another significant problem with existing pressure differential distribution devices may be that the hoses hang in the way of persons. Serpentine-type devices may provide better coverage than a hose reel type device or in-floor systems, but they can be unattractive and intrusive within the facility, because their hose frequently hangs in the way of the workers. See for example, Nederman Inc., *Overhead Exhaust Extractor*, Single and Double Extractor Fans, Drawing No. 13-2, p. 2, hereby incorporated by reference. See also, U.S. Pat. Nos. 5,679,072; 5,791,980; 6,012,978; and 5,362,273, each of which is hereby incorporated by reference, as examples of "hanging hoses".

Another significant problem with existing pressure differential distribution devices may be that the exterior surfaces become hot. High temperature stainless steel or galvanized hose can be prone to becoming dangerously hot when the system moves hot substances, such as emissions from vehicles. The body of the operator, as well as that of other persons, can easily be burned from contact with the heated metal surface. Many of the existing adapters that attach to substance or emission sources may likewise be constructed of metal and thus present the same possibility of inflicting injury. Examples of devices which may become hot are disclosed by Nederman Inc., *Overhead Exhaust Extractor, Single and Double extractor Fans*, Drawing No. 13-2, p. 2; Monoxivent Systems Inc., *Technical Information*, Vehicle Exhaust Damper, Series TCA, p. 3-A; Carmon Products, Inc., Carmon Tube Assemblies, Drawing No. 86-D1, p. 1; Harvey Corp., *Carbon Monoxide Exhaust Removal System*, Harvey Components and Accessories, p. 2; Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1; Nederman Inc., *Nozzles For Vehicle Exhaust Extraction*, Nozzles for Trucks and Other Commercial Vehicles, p. 2, each of which is hereby incorporated by reference.

Another significant problem with existing pressure differential distribution devices which are of the in-floor type may be that they do not completely retract into the floor receptacle or the floor covers may be left open. Persons working around such in-floor devices or open floor receptacles may suffer injury by tripping, or stumbling over strewn components of the emission extraction system, or suffer injury by falling into the open receptacle into which the hose enters. Moreover, the hose outlet assembly, even when operating properly with the floor receptacle closed, may often protrude above the floor surface, presenting similar hazard for those persons working around the device. See for example, Cesco-Advanced Air, *Sales Brochure*, Underfloor Disappearing with Vitrified Clay Pipe, Drawing No. F551-305A378, p. 1 (1978); Ammerman, Inc., Underfloor Automotive Exhaust Systems, Nos. 400, 601, 700, 1000-5, and 1000-6, p. 2; *Technical Manual*, Exhaust-O-Vent, p. 2 (1985); Sacatec, Inc., *Hosereel For Exhaust Extraction*, Cover, p. 1, Harvey Inc., *Carbon Monoxide Exhaust Removal System*, Harvey Overhead Exhaust System, p. 6, each of which is hereby incorporated by reference.

Another significant problem with existing pressure differential distribution devices may be that many components

have hardened, protruding edges or corners or the like which can cause injury to persons. Examples of these devices are disclosed by Nederman Inc., *Overhead Exhaust Extractor*, Nederman Simple Exhaust Extractors, Drawing No. 13-2; Monoxivent Systems Inc., *Technical Information*, Vehicle Exhaust Damper, Series TCA, P. 3-A, Carmon Products, Inc., *Sales Brochure*, Carmon Tube Assemblies, Drawing No. 86-D1, p. 1; Harvey Corp., *Carbon Moxoide Exhaust Removal System*, Harvey Components and Accessories, p. 2, Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1; Nederman Inc., *Overhead Exhaust Extractor*, Nederman Simple Exhaust Extractors, p. 2, each of which is hereby incorporated by reference. See also, U.S. Pat. No. 4,086,847, hereby incorporated by reference, as an example of a device that has "hardened, protruding edges or corners".

Another significant problem with existing pressure differential distribution devices may be that the hands of the operator may be injured if they are caught in the clamping mechanisms. Examples of devices which may pose this type of hazard are disclosed by Monoxivent Systems Inc., *Technical Information*, Vehicle Exhaust Damper, Series TCA, p. 3-A; and Nederman Inc., *Overhead Exhaust Extractor*, Nederman Simple Exhaust Extractors, p. 2, each of which is hereby incorporated by reference.

Yet another problem with existing pressure differential distribution devices may be that when multiple pressure differential distribution devices are connected to a common exhaust fan all draw or expel even when only one device may be in operation. Since many existing devices or the terminal adaptors on such devices are not equipped with a damper or closure, those devices not attached to a source of the substance to be moved will instead draw in the ambient air within the facility and move it external to the facility, or may alternately move air from external to the facility and expel it into the facility. This situation may be problematic because users of a facility may spend larger sums of money to heat or cool the ambient air within their facility. Examples of undampered or non-closured devices are disclosed by Monoxivent Systems Inc., *Technical Information Sheet*, Vehicle Exhaust Damper, Series TCA, p. 3-A; Carmon Products, Inc., *Sales Brochure*, Car-mon Tube Assemblies, Drawing No. 86-D1, p. 1; Harvey Corp., *Carbon Monoxide Exhaust Removal System*, Harvey Components and Accessories, p. 2; Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1, each of which is hereby incorporated by reference. See also, U.S. Pat. No. 4,086,847, hereby incorporated by reference, as an example of a multiple terminal adaptor device not equipped with a damper or closure.

Still another problem with existing pressure differential distribution devices may be that existing terminal interfaces are constructed of metal which may scratch, dent, or otherwise damage the equipment to which they are attached. See for example, metal terminal interfaces disclosed by Nederman Inc., *Overhead Exhaust Extractor*, Nederman Simple Exhaust Extractors, p. 2; Monoxivent Systems Inc., *Technical Information*, Vehicle Exhaust Damper, Series TCA, p. 3-A; Carmon Products, Inc., *Sales Brochure*, Carmon Tube Assemblies, Drawing No. 86-D1, p. 1; Harvey Corp., *Carbon Monoxide Removal System*, Harvey Components and Accessories, p. 2; Monoxivent Systems Inc., Tailpipe Adapter Order Form, p. 1; Nederman Inc., *Nozzles For Vehicle Exhaust Extraction*, Nozzles for Trucks and Other Commercial Vehicles, p. 2, each of which is hereby incorporated by reference.

Another significant problem with existing pressure differential distribution devices may be premature hose failure due to high temperatures on the hose about the point of

attachment to the substance or emission source. This problem can be exacerbated by restrictions that may develop in the hose at the point where it is attached to the emission port, due to the bend radius that may be required for attachment. When the hose is continually restricted, hot spots may develop on the hose which may shorten the life of the hose.

Another problem with existing pressure differential distribution devices may be that the retraction device is complicated. As disclosed by U.S. Pat. No. 5,402,551, "the input shaft is rotatably coupled to the output shaft of the motor. A clutch is disposed between the output shaft of the gear reduction unit and a vacuum hose reel". Similarly, U.S. Pat. Nos. 3,911,944; 4,343,420; and 5,146,349 disclose respectively a "reversible motor . . . switches . . . pusher disposed both in front and in the rear of the hose for actuating switches . . . auxiliary switch for manual control"; a "dual roller configuration" with a "retraction spring" wherein the hose is retracted to comprise three lengths divided by the first and second roller; "pulleys coupled to both wheels and a flexible belt . . . crossing to provide the driving connection between the first wheel and the other wheel to turn them in opposite directions . . . ". Similarly complicated are the "telescoping joints" and "counterweight means" disclosed by U.S. Pat. No. 4,086,847. This level of complexity to retract a hose, or similar component, can be understood to be problematic both with regard to potential malfunctioning of the device and with regard to maintenance of the device.

Another significant problem with existing pressure differential distribution devices may be that the devices are undifferentiated and repetitive, showing numerous incarnations of a few basic concepts and ideas, many of which have been scarcely improved since their introduction. As can be understood from the preceding list of problems and the associated body of disclosed information, that many of the above-mentioned industries that use pressure differential distribution technology have experienced long felt but unresolved needs for improved apparatus and methods. At the present time, pressure differential distribution technology suffers from a dearth of innovative ideas and methods; rather than attempting to create improved and imaginative concepts, the various industries continue to simply rely upon a few basic designs. Although some of these apparatus and methods have existed for decades, all of the above mentioned problems within the emission extraction industry remain. Some of these problems have never been addressed while other have been inadequately addressed.

As relating to pressure differential distribution technology in general, and emission extraction systems specifically, it can be understood there are an array of problems which should be addressed yet remain unresolved. The present invention addresses each the above-mentioned problems and provides practical solutions.

DISCLOSURE OF THE INVENTION

Accordingly, the present invention includes a variety of aspects which may be selected in different combinations based upon the particular application or needs to be addressed. Naturally, as a result of these several different and potentially independent aspects of the invention, the objects of the invention are quite varied.

A broad object of the invention can be to provide a pressure differential distribution system for the movement of fluids such as gases or liquids, or solids. For example, without limiting the scope of the invention, movement of air, emissions from vehicles, water, particulates, foam beads, or

any substance that can be moved on a pressure gradient, either separately or in combination.

Another broad object of an embodiment of the invention can be to provide a pressure differential reaction element that moves similar amounts of substance on a pressure gradient compared to existing devices but requires less space dedicated for installation, operation, or storage.

Another broad object of an embodiment of the invention can be to provide an enclosure in which at least some components of the pressure differential distribution device can retract when not in use. One aspect of this object of the invention can be a pressure differential reaction element that retracts into an enclosure. A second aspect of this object of the invention can be to configure the exterior of the enclosure or hose holster so that it may be more aesthetically pleasing or improve the aesthetics of the facility where the device is installed.

Another broad object of an embodiment of the invention can be to make the components of the pressure differential distribution invention less complicated individually, or in combination, or with regard to how they function. An aspect of this object can be to eliminate hose reels, motors, pulleys, rollers, retraction springs, switches, telescoping joints, or the like to retract the pressure differential device or hose portion of the device.

Another broad object of an embodiment of the invention can be to lower static pressure within the pressure differential distribution device. By lowering the static pressure smaller pressure differential generators may be used to draw or expel substances moved on the pressure gradient within the device.

Another broad object of an embodiment of the invention can be to provide a pressure differential distribution device that is safe to operate. One aspect of this object of the invention can be to eliminate the risk of burning the body of the operator by designing the emission extraction system to be constructed of materials which do not become perilously hot due to contact with heated substances such as exhaust emissions. A second aspect of this object of the invention can be to prevent the pressure differential distribution system from being on the floor of the work space, obviating the possibility that operator will sustain injury by stumbling or tripping over any component. A third aspect of this object of the invention can be to eliminate the potential injuries caused by protruding, hardened components or by pinching spring-operated adapter mechanisms. A fourth aspect of this object of the invention can be to minimize the hazards of the pressure differential device or terminal-adapter from retracting in a reckless manner, or at an unsafe velocity. Specifically, one embodiment of the invention eliminates the above-mentioned "balancer" component which can be dangerous if operated improperly.

Another object of a particular embodiment of the invention can be to provide components that are not excessively heavy, unwieldy and unruly to manipulate or operate. One aspect of this object of the invention can be to eliminate the use of metal components. Yet another object of an embodiment of the invention can be to provide the consumer with an emission extraction system that can be economical in terms of operational costs. One aspect of this object of the invention is the above-mentioned reduction in static pressure. This allows gases, liquids, or solids to flow from the source of the substance to a second zone or outside exhaust vent with minimal resistance. This reduces the horsepower and electrical cost requirements of the pressure differential generator or exhaust fan. A second aspect of this object of the invention can be to utilize a damper that restricts the entry of ambient air into the system. This aspect reduces the amount of tempered air exhausted from the facility and thereby lowers energy related operational costs. A third aspect of this object of the invention can be to manufacture components from materials which will not scratch or otherwise harm the surrounding equipment and vehicles. A fourth aspect of this object of the invention can be to reduce the expense for replacement hose, caused by overheating or hose kinking.

Another object of an embodiment of the invention can be to provide a more mobile pressure differential distribution system.

Another object of an embodiment of the invention can be to eliminate hoses that hang down or protrude from the floor.

Another object of an embodiment of the invention can be to provide a terminal adaptor that has a higher degree of compatibility with various types of containers or emission sources that hold or emit the substances moved on the pressure gradient generated by the pressure differential distribution system.

Another object of embodiments of the invention can be to address the long felt but unresolved need for a pressure differential distribution system that extends or retracts in an uncomplicated manner, and also addresses the need for a smaller enclosure into which the device can be stored during periods of non-operation. The present invention fulfills this long-felt need by providing an invention which simultaneously reduces start-up or operational costs, increases ease of use, improves the safety and environmental working conditions, enhances the aesthetics of the facility, reduces energy usage, and adapts to various and unique emission applications. Each of these problems may find its solution in the present invention, and therefore the invention addresses the long felt needs of the industry and the consumer.

Naturally further objects of the invention are disclosed throughout other areas of specification and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a particular embodiment of a pressure differential distribution system.

FIGS. **1**A and **1**B show particular embodiments of the pressure differential distribution system in an extended conformer (**1**A) and a retracted conformer (**1**B).

FIG. **2** shows a particular embodiment of a pressure differential reaction element having a flexible pressure differential interface and a support element. FIG. **2**A shows a particular embodiment of a maximum volume conformer. FIG. **2**B shows a particular embodiment of a minimum volume conformer.

FIG. **3** shows a particular embodiments of the invention that utilize a mechanical retraction element. FIG. **3**A shows the retraction element comprising a cable attached to a spring rewind cassette. FIG. **3**B shows the cable retracted by a motorized rewind cassette mechanism. FIG. **3**C shows a notched cable retracted by a gear drive motor.

FIG. **4** shows particular embodiments of the invention that incorporate mechanical retraction elements incorporating a set of pulleys. FIG. **4**A shows a cable that is manually lifted or lowered and is secured in the retracted position to a wall cleat. FIG. **4**B shows a manual ratchet winch that provides a method to lift and lower the flexible hose. FIG. **4**C shows the lifting and lowering of the flexible exhaust hose by a counterweight.

FIG. **5** shows particular embodiments of the invention which use retraction elements that utilize elasticity. FIG. **5**A

shows hose retraction by a stretch cord. FIG. **5**B shows the hose retraction accomplished by a long spring.

FIG. **6** shows particular embodiment of a hose holster or enclosure element. FIG. **6**A shows a basic embodiment of the hose holster or enclosure element. FIG. **6**B shows an end view of FIG. **6**A. FIG. **6**C shows a particular embodiment of the hose holster or enclosure element with a particular embodiment of a pressure differential reaction element retracted inside. FIG. **6**D shows a cross section view of FIG. **6**C. FIG. **6**E shows a particular embodiment of a pressure differential reaction element extended from the hose holster of enclosure element. FIG. **6**F shows a cross section view of FIG. **6**E.

FIG. **7** shows particular embodiments of restraint elements used to hold the emission removal adapter to the self-locating hose guide or hose holster. FIG. **7**A shows an restraint element that incorporates notches in the self-locating hose guide, and a pair of non-scratch tabs on the adapter. FIG. **7**B shows a restraint element that utilizes permanent magnets. FIG. **7**C shows an restraint element mechanism that employs a DC electromagnet. FIG. **7**D shows a restraint element that incorporates a trapeze bar attachment device. FIG. **7**E shows restraint element as a chain and hook.

FIG. **8** shows particular embodiments of a pressure differential distribution system enclosure or collapse element enclosure with a collapse element guide. FIG. **8**A shows a side view of a collapse element guide with notches. FIG. **8**B shows a top view of FIG. **8**A. FIG. **8**C shows an enlargement of the top view. FIG. **8**D shows a side view of the collapse element guide with a permanent magnet. FIG. **8**E shows a top view of FIG. **8**D. FIG. **8**F shows an enlargement of the top view. FIG. **8**G shows a side view of the collapse element enclosure with a built-in beveled hose entry guide with notches. FIG. **8**H shows a top view of FIG. **8**G. FIG. **8**I shows an enlargement of the top view of the internal recesses and external flares. FIG. **8**J shows a side view of the collapse element enclosure with a built-in beveled hose entry guide, with notches. FIG. **8**K shows a top view of FIG. **8**J.

FIG. **9** shows a particular embodiment of an emission removal adaptor. FIGS. **9**A–**9**D show particular embodiment of an emission removal adapter with a rotational damper coupled to an adapter sleeve. FIG. **9**A shows a side view of the emission removal adapter. FIG. **9**B shows a front view of the emission removal adaptor. FIG. **9**C shows a side view of the emission removal adapter with the rotational damper closed. FIG. **9**D shows a front view of the emission removal adapter with the rotational damper in an open position.

FIG. **10** shows particular embodiments of dampers to regulate the pressure differential distribution system. FIG. **10**A shows an inlet view of a damper in the closed position. FIG. **10**B shows a side view of a damper in an open position. FIG. **10**C shows a damper in a closed position, with a particular embodiment of a damper rotation control. FIG. **10**D shows a damper blast gate in a partially opened position FIG. **10**E shows a spring operated flap damper. FIG. **10**F shows a manually operated flap damper.

FIG. **11** shows particular embodiments of the invention that rotate or swing. FIG. **11**A shows an internal-external ball socket support. FIG. **11**B shows a side view of a bi-directional swivel support. FIG. **11**C shows a front detail view of the bi-directional swivel support.

FIG. **12** shows particular embodiments of the invention that provide mobility. FIG. **12**A shows a side view of a guide track with a collapse element and collapse element enclosure. FIG. **12**B shows a rail with two trolleys attached to the collapse element with collapse element enclosure. FIG. **12**C shows a side view of a rail.

FIG. **13** shows a particular embodiment of a terminal interface element removal adaptor. FIG. **13**A shows a side view of the terminal interface element in a closed position. FIG. **13**B shows a front view of the terminal interface element in a closed position. FIG. **13**C shows a side view in which the terminal interface element is in an open position. FIG. **13**D shows a front view of the terminal interface element in an open position.

FIG. **14** shows a particular embodiment of a terminal interface element which opens and closes under the force of a spring clamp. FIG. **14**A shows a side view of the emission removal adapter in a closed position. FIG. **14**B shows a side view of the emission removal adapter in an open position.

FIG. **15** shows a particular embodiment of the terminal interface element or emission removal adapter with a friction enhancement surface. FIG. **15**A shows a front view of the emission removal adapter and the friction enhancement surface in a closed position. FIG. **15**B shows a front view of the emission removal adapter and the friction enhancement surface in an open position.

MODE(S) FOR CARRYING OUT THE INVENTION

The invention provides apparatus and methods for the distribution of a pressure differential. While various examples within the description involve the extraction of unwanted or unhealthy emissions from facilities, it is understood that these examples are not meant to limit the scope of the various embodiments of the invention which may be used in a wide variety of applications such as vacuum cleaning systems, ventilation systems, fluid or solid distribution systems, or the like.

As mentioned earlier, the present invention includes a variety of aspects which may be combined in different ways. As can be easily understood, the basic concepts of the present invention may be embodied in a variety of ways. In this application, pressure differential distribution devices and methods of making and using the devices are disclosed. The methods may be disclosed as part of the results shown to be achieved by the various embodiments described or as steps which are inherent to utilization. The methods are simply the natural result of utilizing the devices as intended and described. In addition, while some devices are disclosed, it should be understood that they not only accomplish certain methods but also can be varied in a number of ways. Importantly, as to all of the foregoing, all of these facets should be understood to be encompassed by this disclosure.

As shown in FIG. **1**, a particular embodiment of a pressure differential distribution device may comprise a pressure differential generator (**11**), and a pressure differential reaction element (collapse element, or collapsible hose depending on the particular embodiment of the invention) (**1**). The pressure differential generator (**11**) may be a fan that generates a pressure gradient within the pressure differential reaction element (**1**). The pressure differential generator could generate the pressure gradient in either direction within the pressure differential reaction element (**1**) (either creating an area of high pressure or an area low pressure within the pressure differential reaction element). In other embodiments of the invention, the pressure differential generator could be a pump, a hydraulic or pneumatic device to pressurize fluids, a bellows, or other similar device capable

of generating a difference in pressure between the interior volume of the pressure differential reaction element and the exterior volume separated by the flexible pressure differential interface (**2**).

Referring now to FIG. **2**, an embodiment of a pressure differential reaction element (**1**) is shown. The pressure differential reaction element can have a flexible pressure differential interface (**2**) to maintain a pressure differential between the interior volume defined by the flexible pressure differential interface (**2**) and the exterior volume surrounding it. With regard to some embodiments of the pressure differential reaction element invention, the flexible pressure differential interface (**2**) may have a construction responsive to the difference in pressure between the interior volume and the exterior volume so that the difference in pressure generated by the pressure differential generator (**11**) can be affirmatively used to change the conformation of the flexible pressure differential interface (**2**). The change in conformation in response to the difference in pressure could be to increase the volume of the pressure differential reaction element (**1**) or to decrease the volume of the pressure differential reaction element. The flexible pressure differential interface may be produced from a variety of materials, for example, metal foil, plastic, rubber, fiberglass, silicon impregnated fiberglass, neoprene-polyester, silicon rubber, neoprene rubber, Kevlar, glass yarn, ceramic filler, high temperature glass, or the like, independent of one another, or in combination, or as composites. The selection of materials can be made so as to make the flexible pressure differential interface tolerant of the range of pressures, the types of substances, or the range of temperatures that it may be exposed to. For example, when used to remove high temperature emissions, a material such as glass yarn may be used which can withstand an intermittent temperature of up to about 1500° Fahrenheit. A silicone impregnated fiberglass may be used for emissions having intermittent temperatures between about minus 65° Fahrenheit to about 600° Fahrenheit. Naturally, embodiments of the pressure differential interface (**2**) could be constructed from a plurality of layers, or could for example, have at least two layers comprising an inner layer with a surface responsive to the environment of the interior volume (temperature, chemical, pressure, or otherwise) and an outer layer with a surface responsive to the environment of the exterior volume (temperature, chemical, pressure, or otherwise). While the configuration of the embodiment of the pressure differential reaction element shown in FIG. **2** has a cylindrical geometry, it could be configured in any manner of geometries that could maintain a difference in pressure between the interior volume and the exterior volume. For example, the configuration in cross section could be any polygonal shape, or ovoid type shape, or star type shape, or could even comprise irregular geometries. Each configuration could conform in response to either a positive or negative pressure developed within the pressure differential reaction element.

The invention may also include a support element (**3**). The support element with respect to some embodiments of the invention may be coupled to a portion of the flexible pressure differential interface (**2**). The support element may be coupled to the exterior surface, as shown in FIG. **2**, the interior surface, or between the layers which make up the pressure differential interface (**2**). The support element (**3**) may comprise a plurality of independent supports having closed geometry, such as circles or rectangles, or have open geometry, such as linear or arced segments, coupled to the pressure differential interface (**2**). The support element (**3**) may also have sufficient rigidity to substantially maintain a fixed configuration in response to the pressure differential between the interior volume and the exterior volume. For example, as shown in FIG. **2**, the embodiment of the support element (**3**) shown comprises a continuous helix coupled to the exterior surface of the pressure differential interface (**2**). This embodiment of the support element (**3**) substantially fixes the diameter of the cylindrically configured pressure differential reaction element (**1**) in response to the difference in pressure between the interior and the exterior of the flexible pressure differential interface (**2**) while allowing the length of the cylindrically configured pressure differential reaction element (**1**) to vary as the flexible pressure differential interface (**2**) is conformed by the pressure difference. Naturally, based on the type of support element selected, the fixed configuration of the pressure differential reaction element may have numerous geometries as may be desired in response to varied pressure differences between the interior volume and exterior volume. For example, if the support element shown in FIG. **2** comprised a series of discontinuous arced segments, both the diameter and length of the pressure differential reaction element could be conformed at the same time, or serially, by adjusting the difference in pressure between the interior volume and the exterior volume.

The material of the support element (**3**) may be selected or sized based on the configuration of the pressure differential reaction element (**1**) desired (which could be a variety of geometries as described above), with regard to the application to which it will be used, or the environment to which the support element may be exposed. As such, the support element (**3**) could be made from a variety of materials such as metal, plastic, stainless steel, or plastic coil, or any material having rigidity sufficient to substantially fix the configuration of the pressure differential reaction element to the desired geometry under the force generated by the difference in pressure between the interior volume and the exterior volume. In some embodiments of the invention, the support element (**3**) may even comprise an increased thickness of the flexible pressure differential interface itself.

The support element (**3**) or support helix, as shown in FIG. **2**, can be constructed of a material that arrives at a balance: it must be strong enough to give shape and support the flexible pressure differential interface (**1**) and, in certain applications, to assist the process of retraction; however, it must not be so strong that it pulls the emission removal adapter (**12**) from the emission port (**10**), or to cause the system to become cumbersome or unwieldy to operate.

The pressure differential reaction element (collapse element, or compressible hose) (**1**) can have a substantially smooth bore interior surface when in the extended configuration. As can be understood, the pressure differential interface (**2**), unlike corrugated hose, can conform to a substantially smooth bore surface when extended. A smooth bore surface can lower the static pressure within the pressure differential reaction element (collapse element, or compressible hose) (**1**).

Referring again to FIG. **1**, the invention may also include an adjustable pressure differential regulator to adjust the pressure differential between the interior volume and the exterior volume defined by the pressure differential reaction element (**1**). The adjustable pressure differential regulator may comprise an adjustment device that monitors the difference in pressure and then adjusts the operation of the pressure differential generator (**11**) to maintain the difference in pressure to a predetermined range or amount. Alternately, the adjustable pressure differential regulator may maintain the difference in pressure between the interior volume and exterior volume to the predetermined value by allowing the

exterior volume and the interior volume to be fluidicly responsive to a degree. An example, of this type of adjustable pressure differential regulator (or pressure differential balance element) can be the air bleed in valve **(21)** shown in FIG. **1**. Adjustment of the pressure difference between the interior volume and the exterior volume conforms the flexible pressure differential interface **(2)** not coupled to the support element **(3)**. Alternately, as shown in FIGS. **9**B, **9**D, **10**D, **10**E, and **6**F the adjustable pressure differential regulator may also comprise a variably adjustable closure responsive to the pressure differential reaction element **(1)**. Particular embodiments of the invention may also include a pressure differential selector element **(17)** which, as shown in FIG. **1**, may comprise a damper rotation control.

The pressure differential reaction element (collapse element or compressible hose) **(1)** may also include embodiments that have selectably variable conformer(s) established by the pressure differential between the interior volume and the exterior volume. For example, the selectably variable conformer may conform substantially in only a single direction. For example as shown by FIGS. **1**A and **1**B, a pressure differential reaction element **(1)** having a continuous helical support element **(3)** may conform from an maximum volume conformer as shown in FIG. **1**A (when the flexible pressure differential interface is extended) to a minimum volume conformer as shown in FIG. **1**B (when the flexible pressure differential interface is folded on itself or compressed) where the change in conformation occurs substantially in a single dimension (the length of the pressure differential reaction element with respect to this embodiment of the invention). Naturally, depending on the support element **(3)** used it can be understood that the pressure differential reaction element could have a selectably variable conformer that conforms substantially in only two directions, or could have a selectably variable conformer that conforms in three directions, or more as the application requires. The minimum volume conformer may have a percent volume of the maximum volume conformer of less than about 5%, less than about 10%, less than about 15%, less than about 20%, less than about 25%, less than about 30%, less than about 40% or less than about 50% depending on the particular embodiment of the invention. With respect to the embodiment of the invention shown in FIG. **1**, and when using a type of pressure differential reaction element (collapse element or compressible hose) similar to that shown in FIG. **2**, the compression ratio of the pressure differential reaction element **(1)** can be from about 3:1 to about 6:1 (a 6:1 compression ration means the minimum volume conformer has a percent volume of the maximum volume conformer of about 16%). The pressure differential reaction element **(1)** can also have a minimum bend ratio in the range of about 1.1 times to about 1.9 times the diameter. This bend ratio can be important in preventing overheating as described below. The pressure differential reaction element (collapse element or compressible hose) **(1)** can have external dimensions which vary with respect to the application of the device. The embodiment of the invention shown in FIG. **1** has a diameter that is substantially consistent along the entire length of the pressure differential reaction element. The length can vary between embodiments of the invention. The length of the pressure differential reaction element shown in FIG. **1** can be between about ten feet to about fifty feet in length.

Various substances or emissions moved on the pressure differential can require various levels of air flow, commonly measured in the U.S. emission extraction industry in terms of cubic feet per minute (CFM). In practice, the CFM requirement of an application is the primary determinant of

the diameter of exhaust hose to be used. When the CFM requirement is low, a smaller diameter hose may be employed; when the CFM requirement is high, a larger diameter, but more expensive, hose must be used. This observation illustrates the economic realities of the emission extraction market: more price sensitive components need to be made available to the lower CFM emission applications, while the higher CFM emission applications typically demand more robust and expensive components. Consequently, the pressure differential reaction element (collapse element or compressible hose) **(1)** can be available in various diameters or internal volumes to accommodate the unique economic and performance needs of a particular application. Not only should the diameter or internal volume be available in various sizes, but the pressure differential reaction element **(1)** must also be available in various lengths, depending upon where the emission port (or substance source) **(10)** may be in relation to the facility's ceiling, walls, and other relevant design considerations. Typically, embodiments of the invention can move a volume of gas within the range of about 250 CFM to about 2500 CFM.

Particular embodiments of the invention may further comprise a priority conformer memory element. The priority conformer memory element facilitates establishment of particular pressure differential reaction element conformers. The priority conformer memory element may facilitate establishment of a minimum volume conformer, or a maximum volume conformer, or a conformer used most often. The priority conformer memory element can be responsive to the flexible differential interface **(2)**, or to the support element **(3)**, or can be integral to, or coupled to, either or to both. For example, referring to FIG. **2**, the continuous helix support element **(3)** shown can be provided with a priority conformer memory element so that the coils of the helix are urged together, or the coils can be urged to extend from one another to some degree.

Now referring to FIGS. **3**A–C, these embodiments of the invention provide a variety of alternative devices or methods (other than the difference in pressure between the interior volume and exterior volume), to achieve retraction of the pressure differential reaction element (collapse element or compressible hose) **(1)**. FIG. **3**A offers a spring rewind cassette **(60)** that is mounted on the top of the hose holster **(4)**. There is an internal cable **(59)** that is secured at one end on the spring rewind cassette **(60)** reel, and that may be attached at the other end to the emission removal adapter **(3)**, or adapter sleeve **(18)**. When the operator extends the flexible exhaust hose **(1)**, the spring rewind cassette **(60)** leads out cable **(59)** from an internal cassette drum. When the operator desires to retract the flexible exhaust hose **(1)** into the hose holster **(4)**, the tension on the spring rewind cassette **(60)** aids in the retraction of the flexible exhaust hose **(1)**. FIG. **3**B likewise utilizes a rewind cassette and cable **(59)**; however, the rewind cassette is a motorized rewind cassette **(61)** and has a power supply **(62)**. The motorized rewind cassette **(61)** would have upper and lower limit switches to assure that the flexible exhaust hose **(1)** is neither over extended nor retracted too far into the hose holster **(4)**. Another embodiment, shown in FIG. **3**C, offers a similar motorized drive; however, the cable **(59)** has notches or teeth that allow a gear drive motor **(64)** to lift and lower the flexible exhaust hose **(1)** as the operator activates an up or down motor controls **(64)**. The retraction and extension of the pressure differential reaction element (collapse element or compressible hose) **(1)** can be accomplished when the operator activates the up or down motor

control (**63**) function that drives the gear drive motor (**64**) to either extend or retract the pressure differential reaction element (**1**). The up or down motor control (**63**) may be a simple button type switch, on an flexible cable, mounted on the lower portion of the hose holster (**4**), or the control may be a remote transmitter, or some other type of control device may be utilized.

In addition to or in conjunction with the hose retraction or extension methods above, FIGS. **4**A–C may provide embodiments at a lower cost to the consumer. FIG. **4**A illustrates a method that utilizes a simple pair of pulleys (**65**), cable (**59**), and a wall cleat (**66**). One end of the cable (**59**) is secured to the emission removal adapter (**12**). In this particular embodiment, the cable (**59**) will continue up from the emission removal adapter (**12**), run through the interior of the flexible exhaust hose (**1**), and proceed through the inside of the hose holster (**4**) to the first pulleys of a pair of pulleys (**65**). The cable (**59**) will then proceed over to the second pulley of the pair of pulleys (**65**) and down to the wall cleat (**66**) that is attached to a wall or column and that may be easily grasped by any person within the facility. To extend the emission extraction system, the operator allows the cable (**59**) to slide upwards through the pair of pulleys (**65**), allowing the force of gravity to induce the movement of the emission removal adapter (**12**) out of the hose holster (**4**). To retract, the operator simply pulls downward on the cable (**59**); the pair of pulleys (**65**), as mentioned above, will facilitate the operator's task of retracting the flexible exhaust hose (**1**) into the hose holster (**4**). To ensure that the emission extraction system remains in a retracted position, the wall cleat (**66**) will be securely mounted on the wall, at a convenient height for the operator. The operator may then tie and fasten the cable (**59**) around the wall cleat (**66**) to hold the emission extraction system in the retracted position; when it becomes necessary to extend the emission extraction system, the operator may simply untie the cable (**59**) from the wall cleat (**66**).

FIG. **4**B depicts a particular embodiment of the invention that utilizes a manual ratchet winch (**67**). This embodiment relies on the cable (**59**) and the pair of pulleys (**65**) to extend and retract the emission extraction system. However, to provide further ease of use, the operator may manually turn the manual ratchet winch (**67**) to raise and lower the emission extraction system. The manual ratchet winch (**67**) will provide the operator with leverage in the process of retraction; this benefit of leverage, coupled with the pair of pulleys (**65**), will make the operation of the emission extraction system less strenuous for the operator. The manual ratchet winch (**67**) will contain an automatic locking mechanism to ensure that the emission extraction system remains in the retracted position.

FIG. **4**C shows a particular embodiment of the invention which utilizes cable (**59**) and the pair of pulleys (**65**). However, to facilitate the process of extending and retracting the emission extraction system, this embodiment relies upon a counterweight (**68**). The counterweight (**68**) will be securely fastened to the cable (**59**). In each particular application, the counterweight (**68**) will be calibrated to balance the weight of the corresponding emission removal adapter (**12**) and flexible exhaust hose (**1**), so that there may be no upward or downward movement unless the operator moves the emission extraction system.

Now referring to FIGS. **5**A–B which show particular embodiments of the invention which may be utilized individually or in combination with the above described embodiments of the invention in order to facilitate the task of extension and retraction. The overall lengths and retraction strengths of these embodiments can be selected based on the length of hose (**1**) and specific application requirements. As shown in FIG. **5**A, the emission extraction system may include a stretch cord (**69**), which may be constructed of a material that contains both elastic properties and a memory. The stretch cord (**69**) will be securely attached to the emission removal adapter (**12**). From the emission removal adapter (**12**), the stretch cord (**69**) will run inside the pressure differential reaction element (collapse element or compressible hose)(**1**), and will proceed to a firmly secured attachment device (**70**) inside the lower emission duct (**8**). When the operator extends the emission extraction system for use, the stretch cord (**69**) will stretch, though it is imperative that the elasticity not be so strong that the elastic force pulls the emission removal adapter (**12**) from the emission port (**10**). Once the operator desires to retract the emission extraction system and has disengaged the emission removal adapter (**12**) from the emission port (**10**), the elastic force and compressed memory of the stretch cord (**69**) will assist the retraction of the flexible exhaust hose (**1**) into the hose holster (**4**). As shown in FIG. **5**B, another possible embodiment of the present invention includes the utilization of a spring (**71**). This spring (**71**) will be securely attached to the emission removal adapter (**12**). From the emission removal adapter (**12**), the spring (**71**) will run inside the flexible exhaust hose (**1**), and will be firmly secured to an attachment device (**70**) inside the emission duct (**8**). When the operator extends the emission extraction system for use, the spring (**71**) will stretch, though it is imperative that the elasticity not be so strong that the elastic force pulls the emission removal adapter (**12**) from the emission port (**10**). Once the operator desires to retract the emission extraction system and has disengaged the emission removal adapter (**12**) from the emission port (**10**), the elastic force, and compressed memory of the spring (**71**) will assist the retraction of the pressure differential reaction element (collapse element or compressible hose)(**1**) into the hose holster (**4**).

Now referring to FIGS. **1** and **6**, particular embodiments of the invention may also include an enclosure or a hose holster (**4**) responsive to the pressure differential reaction element (collapse element or compressible hose) (**1**). The enclosure or hose holster (**4**) may have an interior surface configured to receive the pressure differential reaction element in a reduced volume conformer, or can be configured to receive the minimum volume conformer. The enclosure (**4**) may be made from metal, or plastic, or other material which may be configured to provide an interior surface configured to receive particular embodiments of the reduced volume conformers of the pressure differential reaction element (collapse element or compressible hose)(**1**).

The enclosure or hose holster (**4**) not only acts as a receptacle for the pressure differential reaction element (collapse element or compressible hose)(**1**) when in the stored position, but also conceals the pressure differential reaction element (collapse element or compressible hose) (**1**), enhances the appearance of the facility, and protects the flexible exhaust hose (**1**) when not in use. By keeping the flexible exhaust hose (**1**) off the floor, the enclosure or hose holster (**4**) thereby removes a potential safety hazard. The enclosure or hose holster (**4**) may have support components (**7**), appropriate to secure the entire enclosure or hose holster assembly to a given suspension support (**8**) or to the exhaust duct (**9**). The interior configuration of the enclosure or hose holster (**4**) will, of course, be slightly larger than the pressure differential reaction element (collapse element or compressible hose)(**1**) itself, but not so large as to allow the flexible

exhaust hose **(1)** to double back on itself when in the retracted position. The overall length of the hose holster **(4)** can be designed to the desired length of the pressure differential reaction element (collapse element or compressible hose) **(1)**, the compressibility of the flexible exhaust hose, and the given application and installation requirements. The enclosure or hose holster **(4)** could have a variety of external configurations but the interior surface would be typically configured to match the external configuration of the retracted pressure differential reaction element (collapse element or compressible hose)**(1)**. For example, as shown by FIG. **1** or **6**, the enclosure or hose holster **(4)** can be cylindrical in order to match the shape of a cylindrical pressure differential reaction element (collapse element or compressible hose)**(1)**. Examples of enclosure or hose holster **(4)** materials include, but are not limited to, a variety of plastics, fiberglass, or metals. The hose holster **(4)** can be made of a material that is strong enough to retain its shape with continuous and extended usage, but that is light enough to accommodate structural design considerations, or minimize shipping costs.

Now referring to FIG. **7**, the enclosure or hose holster **(4)** may further comprise a self-locating hose guide **(5)**, which may either be manufactured as a single part with the enclosure or hose holster **(4)**, or as a separate component that is attached during installation. The primary purpose of the self-locating hose guide **(5)** can be to assist in the retraction of the pressure differential reaction element (collapse element or compressible hose) **(1)** into the enclosure or hose holster **(4)** and, in certain embodiments, to restrain the emission removal adapter **(12)** in the retracted position, as seen in FIGS. **7**A–E. The size of the self-locating hose guide **(5)** will be determined by both the diameter of the hose holster **(4)** and by the size of the emission removal adapter **(12)** that it may secure. The material selection of the self-locating hose guide **(5)** would typically, but not necessarily, match the materials selected for hose holster **(4)**, as mentioned above.

FIGS. **7**A–E also provide illustrations of various apparatus to restrain the emission removal adapter **(12)** within a self-locating hose guide or self locator element **(5)** or the enclosure or hose holster **(4)** when the system is not in use. The self-locator element affirmatively positions the emission removal adaptor or terminal interface during periods of non-use. The self-locator guide may comprise an exterior surface of the terminal interface and a surface of the self locator guide which are configured to mate. FIG. **7**A offers an embodiment in which the self-locating hose guide **(5)** features notches to provide a resting point for the pair of non-scratch tabs **(16)**. As described above, the emission removal adapter **(12)**, or adapter sleeve **(18)**, has a pair of non-scratch tabs **(16)**; the operator may insert these into the pair of vertical notches **(23)** positioned on the self locating hose guide **(5)**. The operator may then rotate the emission removal adapter **(12)** slightly into the pair of horizontal, inclined notches **(24)**, and the pair of non-scratch tabs **(16)**, held secure by the force of gravity, rest in the pair of horizontal inclined notches **(24)** until the system is needed. To remove the emission removal adapter **(12)**, the operator simply reverses the above mentioned procedure. FIG. **7**B illustrates an alternative embodiment in which a permanent magnet **(35)**, specifically selected for appropriate holding power, is secured into the self-locating hose guide **(5)** or hose holster **(4)**; a corresponding metallic ring **(34)** is fitted onto the adapter sleeve **(18)** or the emission removal adapter **(12)**. When the operator returns the emission removal adapter **(12)** to the self-locating hose guide **(5)** or hose holster **(4)**, the permanent magnet **(35)** magnetically binds the metallic ring **(34)** into a stored position. To remove the emission removal adapter **(12)**, the operator simply tugs on the emission removal adapter **(12)** until the metallic ring **(34)** releases from the permanent magnet **(35)**. FIG. **8**C illustrates an alternative embodiment in which a DC electromagnet **(36)** is secured to the self-locating hose guide **(5)** or hose holster **(4)**, and a corresponding metallic ring **(34)** is fitted onto the adapter sleeve **(18)**, or emission removal adapter **(12)**. When the operator returns the emission removal adapter **(12)** to the self-locating hose guide **(5)** or hose holster **(4)**, the DC electromagnet **(36)** magnetically binds the metallic ring **(34)** of the emission removal adapter **(3)** into a stored position. To remove the emission removal adapter **(12)**, the operator simply interrupts the power to the DC electromagnet **(36)** by operating a conveniently located electrical switch **(37)**. The power for the DC electromagnet **(36)** is supplied by a safe, low voltage DC power supply **(38)**. FIG. **7**D offers an embodiment that secures the emission removal adapter **(12)** with a trapeze bar **(39)**. The trapeze bar **(39)** may be attached to the hose holster **(4)**, and will be manually moved to the side by the operator when the flexible exhaust hose **(1)** is being extended or retracted. Once the flexible exhaust hose **(1)** has been retracted, the operator will simply allow the trapeze bar **(39)** to swing back to a vertical position, and the emission removal adapter **(12)** would lower itself to a resting position on the trapeze bar **(39)**. To release the emission removal adapter **(12)** for usage, the operator would swing the trapeze bar **(39)** to the side, and the emission removal adapter **(12)** and the flexible exhaust hose **(1)** would thus be released. FIG. **7**E offers an embodiment in which the emission removal adapter **(12)** has a length of chain **(40)** attached thereto. Fastened to the opposite end of the attached chain **(40)** is a hook **(41)**. When the emission removal adapter **(12)** is retracted to a stored position, the operator may attach the hook **(41)** to a hole **(42)** in the hose holster **(4)**. To release the emission removal adapter **(12)**, the hook **(41)** is simply removed from the hole **(42)** in the hose holster **(4)**. As can be understood, other apparatus to restrain the emission removal adapter **(12)** may be used and may either be attached to the self-locating hose guide **(5)**, or directly to the hose holster **(4)**.

FIGS. **8**A–K offer different embodiments of the enclosure or hose holster **(4)**, holster support components **(7)** or self-locating hose guides **(5)**. FIG. **8**A depicts a particular embodiment in which the hose holster **(4)** includes a holster support component **(7)** featuring a rib-like flange design, which is in turn secured to a holster support **(8)**. A top view of the hose holster **(4)**, the holster support component **(7)**, and the self-locating hose guide **(5)** is provided in FIG. **8**B. FIG. **8**C shows a top view detail of the holster support component **(7)** with the rib-like flange bolted to an angle iron suspension support **(8)**. Pre-drilled fastener holes in the holster support component **(7)** will increase the ease of installation and will reduce installation time. A different embodiment, shown in FIG. **8**D, offers a hose holster **(4)** that includes a holster support component **(7)** with a tubular flange design that is secured to a suspension support **(8)**. FIG. **8**E shows a top view of the hose holster **(4)**, the holster support component **(7)**, and self-locating hose guide **(5)**. FIG. **8**F shows a top view detail of the holster support component **(7)** with the tubular flange design that receives a circular support shaft and is held secure to the holster support **(8)** by fasteners. Once again, pre-drilled fastener holes, in the holster support component **(7)**, will increase the ease of installation and will reduce installation time. FIG. **8**G offers a particular embodiment showing the hose holster

(4) with a beveled hose entry guide (43), and a holster support component (7) with internal recesses and external flares for fastening to a suspension support (8). FIG. 8H shows a top view of the hose holster (4), and the holster support component (7). FIG. 81 shows a top view detail of the holster support component (7) with internal recessed and external flares, bolted to an angle iron suspension support (8). Pre-drilled fastener holes, in the holster support component (7), will increase the ease of installation, and will reduce the installation time. In FIG. 8J, a particular embodiment shows the hose holster (4) with a beveled hose entry guide (43), and with the hose holster (4) secured to the holster support (8) by holster support clamps (44). FIG. 8K shows a top view of the hose holster (4) and the holster support clamps (44).

Now referring to FIG. 9, the invention may further comprise an emission removal adapter (12). Just as the flexible exhaust hose (1) may be embodied in various ways embodiments of the emission removal adapter (12) may likewise be varied, depending upon the application. For example, automotive facilities, which comprise a substantial portion of the lower CFM emission removal marketplace, are generally very price sensitive. Conversely, higher CFM emission removal applications, such as heavy equipment maintenance facilities, typically demand higher performance and quality products, and these consumers are generally willing to pay the associated higher costs.

The emission removal adapter (12) serves the important function of collecting emissions at a source (10). Because the emission removal adapter (12) is the component of the system that most often will be physically handled by the operator, it is preferred that its design should promote both safety and ease of use. As shown in FIGS. 9A–D, the exterior of the emission removal adapter (12) can be constructed of a pliable material. The flexibility of this pliable material (13) can allow the emission removal adapter (12) to assume a variety of positions, enabling it to connect to a wide variety of sources or emission ports. An oval shape provided with some embodiments of the invention allows the operator to easily connect the emission removal adapter (12) not only to single, but also to a plurality of sources such as the dual emission ports, which are commonly found on higher performance vehicles.

In addition to being pliable, it is preferred that this pliable material also withstand the high temperatures of emissions. The pliable material should not substantially warp, expand, or deform relative to its original shape due to continuous contact with hot emissions. Furthermore, it is preferred that the emission removal adapter (12) be constructed from a material which may be exposed to heat for extended periods of time. Possible pliable materials include, but are not limited to, neoprene rubber, or silicone.

As can be readily understood, it is essential to the successful performance of certain embodiments of the invention that limited amounts substance or emissions from the emission port or substance source (10) should escape into the ambient air. By itself, the draw of air created by the operation of the exhaust fan (11) will be adequate to collect the emissions and discharge them to the outdoors. However, for emissions to be drawn effectively, it is preferred that the emission removal adapter (12) remain securely upon the emission port (10). To accomplish this aim, as shown by FIGS. 9A–D, the emission removal adapter (12) includes an adapter securing element (14), which ensures that once the operator sleeves the emission removal adapter (12) over the emission port (10), the connection remains secure. The adapter securing element (14) may be embodied as a flexible

stretch cord, or as a flexible non-stretch cord. At the anterior end of the cord can be a non-scratch hook, which may be attached to a fastening point—for example, the bumper of the vehicle. As seen in FIG. 9A and FIG. 9B, the gripping cleat (15) is used to keep the cord in place. Once the operator secures the hook, he/she may grip the cord tightly, at the opposite end from the hook, and pulling the cord increasingly taut, he/she presses the cord deeper into the "V" channel of the gripping cleat (15), thereby securing not only the cord, but also the emission removal adapter (12). To remove the adapter securing element (14), the cord is loosened from the "V" channel of the gripping cleat (15), the non-scratch hook falls away, and the emission removal adapter (12) may be retracted. To keep the cord from detaching from the eyelet of the gripping cleat (15), the opposite end of the cord may be flared. The gripping cleat (15) has a built-in eyelet that prevents the cord from detaching, since the diameters of both the hook and flare ends are larger than the diameter of the eyelet. However, the diameter of the eyelet will be large enough to allow the cord to readily slide back and forth for attachment and detachment purposes. The gripping cleat (15) will typically be made from a plastic or metal mold. Also, as seen in FIG. 9C and FIG. 9D, a cam type gripping cleat (25) may serve to regulate the length and restrain the movement of the adapter securing element (14).

The shape and diameter of the emission removal adapter (12) may be different from the shape and diameter of the flexible exhaust hose (1). Therefore an adapter sleeve (18) may be used to assist in the transition of these various shapes and diameters. Additionally, the adapter sleeve (18) may provide the location for the pair of non-scratch tabs (16), the damper rotation control (17), the rotational damper (19), the damper seal ring (20), the air bleed-in valve (21), as well as place for securing the flexible protective sleeve (22). The rotational damper (19) would typically pivot on a center axis and would be positioned according to the setting of a damper rotation control (17), directly attached to the same axis. Typically the rotational damper (19) may be made from metal, though high temperature plastics may also be utilized. The damper rotation control (17) may be a dial, as shown in FIGS. 3A–D, or a lever, as shown in FIG. 10C; in either design, the damper rotation control (17) materials would be non-scratching and non-heat dispensing. To assure a seal around the rotational damper (19) perimeter, a damper seal ring (20) is located to limit air leakage. The ability to seal the air flow created by the exhaust fan (11) may be essential to assisting hose retraction, and is also needed to prevent the exhausting of ambient air out of the facility. When not in use, the rotational damper (19) may be in a closed position, as seen in FIGS. 9A–B; when in use, the rotational damper (19) would be turned to an open position, as shown in FIGS. 9C–D.

As shown by FIGS. 9A–D, the pair of non-scratch tabs (16) may be attached to the same axis that holds the rotational damper (19) and the damper rotation control (17). The purpose of the pair of non-scratch tabs (16) is to help secure the emission removal adapter (12) to the hose holster (4) or self-locating hose guide (5).

When the pressure differential generator (11) is in operation, there is a possibility, due to the negative pressure, that excessive stress may be exerted on the flexible hose (1) and the emission removal adapter (12); this potential occurrence may be obviated by the presence of an air bleed-in valve (21), as shown in FIGS. 9A–D. In applications where necessary, the air bleed-in valve (21) may relieve excessive pressure by permitting ambient air to enter the system. The

air bleed-in valve (**21**) may, but is not limited to, operate under a spring load that is calibrated to open up when the negative pressure exceeds a predetermined threshold.

Also illustrated in FIG. **9**A and FIG. **9**B is a flexible, protective sleeve (**22**) that may be constructed of a flex-like metal or plastic material that is the same outside diameter as the adapter sleeve (**18**). Although this is not generally required in low emission applications, this may be particularly useful in higher temperature, higher CFM applications. This flexible, protective sleeve (**22**) would fit inside the lower anterior section of the flexible, exhaust hose (**1**). Attachment to the adapter sleeve (**18**), or emission removal adapter (**12**), may be accomplished by a variety of common manufacturing practices. In certain application, the flexible, protective sleeve (**22**), may protect the lower anterior end of the flexible exhaust hose (**1**) from potentially excessive emission temperatures and from the kinking caused by too severe a bend radius during emission port (**10**) attachment.

As shown in FIGS. **10**A–F, the present invention may utilize a damper that may be built into an emission removal adapter (**12**) or the adapter sleeve (**18**). These include, but are not limited to, apparatus such as a rotational damper (**19**), a blastgate (**31**), a spring operated flap damper (**32**), a manually operated flap damper (**33**), or otherwise. As shown in FIGS. **10**A–B, a rotational damper (**19**) is fitted into the adapter sleeve (**18**) and is manually opened or closed by a damper rotation control (**17**). When the dampening mechanism is placed in the closed position, it may assist in the retraction of the pressure differential reaction element (collapse element or compressible hose) (**1**) into the enclosure or hose holster (**4**) by working in conjunction with the pressure differential generator (**11**) to create the negative pressure required for assisting retraction. Further assisting the process of retraction, shown in FIGS. **10**A–C, is a damper seal ring (**20**), which prevents leakage around the perimeter of the rotational damper (**19**), when in the closed position. In FIGS. **10**A–B, a damper rotation control (**17**) is embodied as a dial, which the operator rotates to open or close the rotational damper (**19**). In FIG. **10**C, the damper rotation control (**17**) is embodied as a lever. A dampening mechanism will be in the opened position, when the pressure differential distribution system is attached to an emission port (**10**), as to allow the pressure differential generator (**11**) to move substances such as unwanted emissions. One possible embodiment is depicted in FIG. **10**D, in which a blastgate (**31**) is inserted into the adapter sleeve (**18**). To control the dampening of air, the operator manually raises and lowers the blastgate (**31**), thereby permitting or restricting the flow of air through the adapter sleeve (**18**). Another possible embodiment, shown in FIG. **10**E, includes the use of a spring operated flap damper (**32**), which is located at the mouth of the emission removal adapter (**12**). Yet another possible embodiment is shown in FIG. **10**F, in which a manually operated flap damper (**33**) is placed on the mouth of the emission removal adapter (**12**). As can be understood, other air dampening components may alternatively be used.

In certain applications, it may be desirable to provide added mobility to the emission extraction system. To accomplish this aim, FIGS. **11**A and **11**B show embodiments that allow a fixed mounted system to offer limited movement. FIG. **11**A shows an pressure differential distribution system suspended from a ball socket support, which consists of an internal ball-socket support (**45**) that fits inside an external ball-socket support (**46**). The internal ball-socket support (**45**) directly supports the pressure differential distribution system, while the external ball-socket support (**46**) is directly supported to the heavy gauge exhaust duct (**9**). The external ball-socket support (**46**) has a cutout in its lower hemisphere to accommodate the internal ball-socket support (**45**) rotational movement. This particular embodiment provides the user with limited rotational movement, offering improved system coverage and the ability to move the pressure differential distribution system when required. The particular embodiment of FIG. **1**B shows an pressure differential distribution system that gains mobility via a bi-directional swivel support (**47**). FIG. **11**C offers a front detail of the connection area, showing the emission extractor system to be supported by a single holster-swivel support pin (**48**) that is fastened to the bi-directional swivel support (**47**). This particular embodiment provides the user with back and forth movement, offering enhanced coverage and the ability to swing the emission extraction system out of the path of interfering objects.

Now referring to FIG. **12**, a pressure differential manifold (**9**) can be joined between the pressure differential generator (**11**) and a plurality of pressure differential reaction elements (**1**). The pressure differential generator would be sized to properly operate all the plurality of pressure differential reaction elements depending on the application and size as would be known to those skilled in the art.

In certain applications, it may be desirable move the emission extraction system along an extended linear path. The ability to move the system along a track may be especially important in applications in which the emission port(s) are changing locations intermittently. Furthermore, the ability to transport the emission extraction system along a track may allow the consumer to reduce expense by utilizing one emission extraction for multiple bays, rather than purchasing separate systems for each bay. In order to accomplish this, FIGS. **12**A and **12**B show embodiments that allow an pressure differential distribution system(s) to have extended linear movement. FIG. **12**A depicts a particular embodiment of an pressure differential distribution system that is suspended from a vertical to horizontal support elbow (**49**), that is in turn hung from a guide track (**51**) by an undercarriage to guide track support (**52**). A collapsible hose (**50**), which may have the same properties and specifications as the flexible exhaust hose (**1**), connects at one end to the vertical to horizontal support elbow(**49**) and at the other end to the exhaust duct (**9**). The undercarriage to guide track support (**52**) allows both the collapsible hose (**50**) and the vertical to horizontal support elbow (**49**) to glide back and forth on the guide track (**51**). Consequently, the emission extraction system may be easily transported anywhere along the length of the guide track (**51**). The entire assembly is suspended by attaching the guide track (**51**) to suspension support (**8**). As seen in FIG. **12**B, a particular embodiment of the invention offers one or more pressure differential distribution systems to be suspended from a common emission plenum rail (**53**). The emission plenum rail (**53**) would typically be utilized in applications that demand multiple emission extraction systems, and require longer linear coverage area than the guide track (**51**) can provide. FIG. **12**B shows both a fixed-mounted and a ball-and-socket mounted emission extraction system, attached to an emission trolley (**54**) by a trolley adapter (**56**). The entire emission trolley assembly moves back and forth along the emission plenum rail (**53**) on trolley wheels (**55**). Depending on the design and application requirements, the emission plenum rail (**53**) may have one or more rail to duct adapters (**57**) that transfer the emissions to the exhaust duct (**9**). In FIG. **12**C, a side view of the rail is shown, indicating that a pair of pliable air sealing flaps (**58**) may be used to

assure that emissions do not escape the emission plenum rail **(53)**, when the emission trolley **(54)** is moved along its length.

FIGS. **13**A–D show a particular embodiment of the invention having a terminal interface element **(23)**. This embodiment of the invention may comprise a variably adjustable aperture element **(26)**, where the variably adjustable aperture element coordinates a location of a first pair of axes **(27)** on a first plane of movement with a location of a second pair of axes **(28)** on a second plane of movement. An adaptor element **(18)** coupled to the pressure differential reaction element (collapse element or compressible hose)**(1)**, and a body **(29)** responsive to the variably adjustable aperture element **(26)** and the adaptor element **(18)**. As can be understood, the first pair of axes on the first plane of movement and the second pair of axes on the second plane of movement can be hingedly responsive to each other. When one pair of axis moves it may necessitate the movement of the second pair of axes on the second plane of movement and vice versa. Axes may broadly encompass flexible seams in the body of the terminal interface element or may even encompass a deflection apex in the material of the body. The variably adjustable aperture element may further comprise an aperture seal to minimize the flow of air through the terminal interface when not in use. A pressure differential regulator may maintain a consistent pressure differential regardless of the size of the variably adjustable aperture element. As shown by FIG. **13**B, the sides of the variably adjustable aperture element **(26)** may rest against one another, creating a tight seal. Thus, while the emission extraction system is not in operation, all terminal interface elements **(23)** may remain tightly shut due to the variably adjustable aperture element **(26)**. The terminal interface element **(23)** may also include an aperture position memory element **(25)** responsive to the variable adjustable aperture element **(26)**. For example, this may involve self-closing or self opening features. The self-closing feature of the variably adjustable aperture element **(26)** may serve as a damper to assist in the retraction of the pressure differential reaction element (or collapse element or compressible hose)**(1)** by the vacuum created by the pressure differential generator **(11)**, can prevent the draw of ambient air from the facility, or can secure the terminal interface element **(23)** or emission removal adapter **(12)** to the emission port **(10)**. There is an array of possible mechanisms to provide an aperture position memory element to self-close the variably adjustable aperture element; these include, but are not limited to, a pair of torsion springs, a pair of band springs, or a memory-molded rubber or plastic product. The mouth closure element **(26)** may have a closure memory to remain in a closed position, as shown in FIGS. **13**A and **13**B. The interior of the body may be configured to mate with a source of the substance to be moved by the pressure differential between the interior volume and the exterior volume. One example of this may be embodied as a tongue **(73)** responsive to the interior surface of the body which is configured to fit in or around particular shaped emission or substance source hardware. A friction enhancement surface may be coupled to the interior surface of the body or on the surfaces of the variably adjustable aperture element. This may consist of an applied material with a textured surface, or the interior of the body or the variable adjustable aperture element may have a textured surface. Naturally, any surface feature which improves the grip of the terminal interface to the source would be a friction enhancement feature such as the interdigitated teeth show by FIGS. **15**A and **15**B.

When the pressure differential distribution system is to be placed into operation, the operator may open the variably adjustable aperture element **(26)** of the terminal interface element **(23)** by placing their hands on each side of the variably adjustable aperture element **(26)** and by pushing both side towards each other, exerting force against the resistance of the variably adjustable aperture element **(26)** or aperture position memory element **(25)**. Under the pressure of the operator, the variably adjustable aperture element **(26)** can assume an open position, as shown in FIGS. **13**C–D. With the variably adjustable aperture element **(26)** in an open position, the operator may easily slide the variably adjustable aperture element **(26)** over the emission port **(10)**. By releasing pressure on the sides of the variably adjustable aperture element **(26)**, the aperture position memory element **(25)** of the variably adjustable aperture element **(26)** may cause the variably adjustable aperture element **(26)** to attempt to return to a closed position. Consequently, the mouth of the variably adjustable aperture element **(26)** will tighten and clench around the emission port **(10)**, and will stay in place until the operator releases the variably adjustable aperture element **(26)** by reversing the procedure.

Other possible embodiments, shown in FIGS. **13**A–D, include a pair of push-grip knobs **(29)**, attached to the variably adjustable aperture element **(26)**. The pair of push-grip knobs **(29)** would typically be constructed of a scratch resistant, non-heat transferable material. A flexible seam **(27)** which runs the length of both sides of the body of the terminal interface element **(23)** may provide enhanced flexibility at specific locations on the terminal interface element **(23)**.

As can be seen in FIGS. **14**A–B, other possible embodiments are available to close the variably adjustable aperture element **(26)**. In this particular embodiment, a spring clamp **(72)** is attached to the variably adjustable aperture element **(26)** and provides the necessary force to close the mouth, as seen in FIG. **14**A. By pushing the handles together, the operator may open the emission removal adapter **(12)** into an open position, as seen in FIG. **14**B. In the closed position, the ends of the curved handles will facilitate the same purpose as the pair of non-scratch tabs **(16)**.

To allow the variably adjustable aperture element **(26)** to better fasten to the emission port **(10)**, one embodiment of the present invention provides for a friction enhancement surface **(30)** in the mouth of the variably adjustable aperture element **(26)**, as shown in FIG. **14**A and FIG. **14**B. A possible example of a friction enhancement surface **(30)** may be interdigitating expanded surface areas, by which the variably adjustable aperture element **(26)** will form a tight seal when in the closed position, as depicted in FIG. **14**A. When the variably adjustable aperture element **(26)** is in the open position, as seen in FIG. **14**B, the friction enhancement surface **(30)** may grab and clench onto the emission port **(10)**, thus ensuring that the variably adjustable aperture element **(26)**), once engaged, will remain securely attached to the emission port **(10)**. In this embodiment, the variably adjustable aperture element **(26)** will have a closure memory of its own, facilitated by the selection of the material's physical characteristics. Because of this built-in closure memory, no spring type mechanism would be required to close the variably adjustable aperture element **(26)**.

As can be easily understood from the foregoing, the basic concepts of the present invention may be embodied in a variety of ways. It involves both emission removal techniques as well as devices to accomplish the appropriate emission removal. In this application, the emission removal techniques are disclosed as part of the results shown to be

achieved by the various devices described and as steps which are inherent to utilization. They are simply the natural result of utilizing the devices as intended and described. In addition, while some devices are disclosed, it should be understood that these not only accomplish certain methods but also can be varied in a number of ways. Importantly, as to all of the foregoing, all of these facets should be understood to be encompassed by this disclosure.

The discussion included in this provisional application is intended to serve as a basic description. The reader should be aware that the specific discussion may not explicitly describe all embodiments possible; many alternatives are implicit. It also may not fully explain the generic nature of the invention and may not explicitly show how each feature or element can actually be representative of a broader function or of a great variety of alternative or equivalent elements. Again, these are implicitly included in this disclosure. Where the invention is described in device-oriented terminology, each element of the device implicitly performs a function. Apparatus claims may not only be included for the device described, but also method or process claims may be included to address the functions the invention and each element performs. Neither the description nor the terminology is intended to limit the scope of the claims which will be included in a full patent application.

It should also be understood that a variety of changes may be made without departing from the essence of the invention. Such changes are also implicitly included in the description. They still fall within the scope of this invention. A broad disclosure encompassing both the explicit embodiment(s) shown, the great variety of implicit alternative embodiments, and the broad methods or processes and the like are encompassed by this disclosure and may be relied upon when drafting the claims for the full patent application. It should be understood that such language changes and broad claiming will be accomplished when the applicant later (filed by the required deadline) seeks a patent filing based on this provisional filing. The subsequently filed, full patent application will seek examination of as broad a base of claims as deemed within the applicant's right and will be designed to yield a patent covering numerous aspects of the invention both independently and as an overall system.

Further, each of the various elements of the invention and claims may also be achieved in a variety of manners. This disclosure should be understood to encompass each such variation, be it a variation of an embodiment of any apparatus embodiment, a method or process embodiment, or even merely a variation of any element of these. Particularly, it should be understood that as the disclosure relates to elements of the invention, the words for each element may be expressed by equivalent apparatus terms or method terms—even if only the function or result is the same. Such equivalent, broader, or even more generic terms should be considered to be encompassed in the description of each element or action. Such terms can be substituted where desired to make explicit the implicitly broad coverage to which this invention is entitled. As but one example, it should be understood that all actions may be expressed as a means for taking that action or as an element which causes that action. Similarly, each physical element disclosed should be understood to encompass a disclosure of the action which that physical element facilitates. Regarding this last aspect, as but one example, the disclosure of a "holster" should be understood to encompass disclosure of the act of "holstering"—whether explicitly discussed or not—and, conversely, were there only disclosure of the act of "holstering", such a disclosure should be understood to encompass disclosure of a "holster" and even a means for "holstering" Such changes and alternative terms are to be understood to be explicitly included in the description.

Any references mentioned, including but not limited to federal or state statutes, patents, publications, brochures, marketing materials, or inter-net pages, in this patent application, are hereby incorporated by reference or should be considered as additional text or as an additional exhibits or attachments to this application to the extent permitted; however, to the extent statements might be considered inconsistent with the patenting of this/these invention(s) such statements are expressly not to be considered as made by the applicant. Further, the disclosure should be understood to include support for each feature, component, and step shown as separate and independent inventions as well as the various combinations and permutations of each.

In addition, unless the context requires otherwise, it should be understood that the term "comprise" or variations such as "comprises" or "comprising", are intended to imply the inclusion of a stated element or step or group of elements or steps but not the exclusion of any other element or step or group of elements or steps. Such terms should be interpreted in their most expansive form so as to afford the applicant the broadest coverage legally permissible in countries such as Australia and the like. Such terms are intended to have an inclusive meaning rather than an exclusive one and should be interpreted in their most expansive form so as to afford the applicant the broadest coverage legally permissible. Therefore, in countries such as Australia and the like, such terms are not intended to have an exclusive, or more limited meaning.

Thus, the applicant(s) should be understood to claim at least: i) each of the pressure differential distribution systems as herein disclosed and described, ii) the related methods disclosed and described, iii) similar, equivalent, and even implicit variations of each of these devices and methods, iv) those alternative designs which accomplish each of the functions shown as are disclosed and described, v) those alternative designs and methods which accomplish each of the functions shown as are implicit to accomplish that which is disclosed and described, vi) each feature, component, and step shown as separate and independent inventions, vii) the applications enhanced by the various systems or components disclosed, viii) the resulting products produced by such systems or components, and ix) methods and apparatuses substantially as described hereinbefore and with reference to any of the accompanying examples, and x) the various combinations and permutations of each of the elements disclosed.

We claim:

1. A method of distributing a pressure differential comprising the steps of:

a. collapsing a flexible pressure differential interface with the assistance from a repositionable closure element that creates an airflow restriction when moved to a closed position, wherein a portion of said flexible differential interface is coupled to a support element, and wherein said flexible pressure differential interface establishes an interior volume and an exterior volume, and wherein said support element has sufficient rigidity to maintain a substantially fixed configuration in response to a pressure differential between said interior volume and said exterior volume; and

b. establishing a minimum volume conformer of said pressure differential interface, wherein said minimum

volume conformer collapses into an enclosure having an interior volume configured to receive said minimum volume conformer.

2. A method of distributing a pressure differential as described in claim 1, wherein collapsing a flexible pressure differential interface comprises collapsing said flexible pressure differential interface with a pressure differential between said interior volume and said exterior volume separated by said flexible pressure differential interface.

3. A method of distributing a pressure differential as described in claim 2, further comprising the step of selecting a volume of said flexible pressure differential interface, wherein said volume is selected by adjusting said pressure differential between said interior volume and said exterior volume.

4. A method of distributing a pressure differential as described in claim 3, further comprising the step of establishing a maximum volume conformer.

5. A method of distributing a pressure differential as described in claim 4, wherein said step of establishing a minimum volume conformer of said pressure differential interface comprises establishing a minimum volume conformer having a percent volume of said maximum volume conformer selected from the group consisting of less than 5%, less than 10%, less than 15%, less than 20%, less than 25%, less than 30%, less than 40%, and less than 50%.

6. A method of distributing a pressure differential as described in claim 5, wherein said step of establishing a minimum volume conformer having a percent volume of said maximum volume conformer comprises variably adjusting conformation of said flexible pressure differential interface with said pressure differential between said interior volume and said exterior volume substantially in one dimension.

7. A method of distributing a pressure differential as described in claim 6, which further comprises the step of facilitating establishment of said minimum volume conformer with a priority conformer memory element.

8. A method of distributing a pressure differential as described in claim 7, wherein said step of facilitating establishment of said minimum volume conformer with a priority conformer memory element comprises coupling said memory element to said flexible pressure differential interface.

9. A method of distributing a pressure differential as described in claim 8, wherein said step of facilitating establishment of said minimum volume conformer with a conformer memory element comprises coupling said memory element to said support element.

10. A method of distributing a pressure differential as described in claim 9, further comprises the step of balancing said pressure differential between said interior volume and said exterior volume to maintain a consistent pressure differential.

11. A method of distributing a pressure differential as described in claim 10, wherein said step of coupling a portion of said flexible pressure differential interface to a support element having sufficient rigidity to maintain at least a minimum volume conformer in response to said difference in pressure between said interior volume and said exterior volume comprises coupling a plurality of independent supports to said flexible pressure differential interface.

12. A method of distributing a pressure differential as described in claim 10, wherein said step of collapsing a flexible pressure differential interface, wherein a portion of said flexible differential interface is coupled to a support element, and wherein said flexible pressure differential interface establishes an interior volume and an exterior volume, and wherein said support element has sufficient ridgity to maintain a substantially fixed configuration in response to a pressure differential between said interior volume and said exterior volume comprises coupling a continuous helix to said flexible pressure differential interface.

13. A method of distributing a pressure differential as described in claim 11 or 12, further comprises the step of establishing said minimum volume conformer within a minimum volume conformer enclosure.

14. A method of distributing a pressure differential as described in claim 13, further comprises the step of coupling a terminal interface element to said pressure differential reaction element.

15. A method of distributing a pressure differential as described in claim 14, wherein said step of coupling a terminal interface element to said pressure differential reaction element comprises coupling a first pair of axis on a first plane of movement and a second pair of axis on a second plane of movement, whereby said first pair of axis on said first plane of movement and said second pair of axis on said second plane of movement are hingedly responsive.

16. A method of distributing a pressure differential as described in claim 15, further comprising the step of coordinating a location of said first pair of axis on said first plane of movement by adjusting a location of said second pair of axis on said second plane of movement to variably adjust an aperture.

17. A method of distributing a pressure differential as described in claim 16, further comprising the step of maintaining a consistent difference in pressure between said interior volume and said exterior volume separated by said flexible pressure differential interface independent of aperture size.

18. A method of distributing a pressure differential as described in claim 17, further comprising the step of coupling said terminal interface to a source of a substance.

19. A method of distributing a pressure differential as described in claim 18, further comprising the step of moving said substance with said pressure differential between said interior volume and said exterior volume.

20. A pressure differential distribution device, comprising:

a. a pressure differential generator;

b. a compressible hose coupled to said differential generator, wherein said compressible hose has an interior surface and an exterior surface, and wherein said compressible hose has a supporting helix joined to a portion of said exterior surface, and wherein said compressible hose has an extended configuration and a compressed configuration;

c. a repositionable closure hose retraction element responsive to said hose; and

d. a hose holster having an interior volume configured to receive said compressible hose wherein said compressible hose is assisted in retraction by said repositionable closure hose retraction element by creating an airflow restriction when moved to a closed position.

21. A pressure differential distribution device as described in claim 20, wherein said supporting helix joined to said portion of said exterior surface has a cylindrical configuration.

22. A pressure differential distribution device as described in claim 21, wherein said supporting helix joined to said portion of said exterior surface comprises a material selected from the group consisting of stainless steel, galvanized steel, and plastic coil stock.

23. A pressure differential distribution device as described in claim 20, wherein said interior surface of said compressible hose has a substantially smooth bore interior surface when in said extended configuration.

24. A pressure differential distribution device as described in claim **20**, wherein said extended configuration and said compressed configuration have a minimum compression ratio from about 3 to 1 to about 6 to 1.

25. A pressure differential distribution device as described in claim **20**, wherein said compressible hose has a minimum bend ratio within the range of about 1.1 to about 1.9 times the diameter.

26. A pressure differential distribution device as described in claim **20**, **21**, **22**, **23**, or **24**, wherein said compressible hose has an internal diameter selected to handle airflow volumes within the range of about 250 cubic feet per minute to about 2500 cubic feet per minute.

27. A pressure differential distribution device as described in claim **26**, wherein said compressible hose has a substantially consistent internal diameter along the entire length.

28. A pressure differential distribution device as described in claim **27**, wherein said compressible hose has a substantially consistent external diameter along the entire length.

29. A pressure differential distribution device as described in claim **28**, wherein said compressible hose has a length within the range of about 10 feet to about 50 feet.

30. A pressure differential distribution device as described in claim **29**, wherein said flexible hose comprises a material selected from the group consisting of silicon impregnated fiberglass, neoprene-polyester, silicon rubber, neoprene rubber, Kevlar, glass yarn, ceramic filler, and high temperature glass.

31. A pressure differential distribution device as described in claim **30**, wherein said flexible hose has a tolerance to temperatures up to about 1500° Fahrenheit intermittent.

32. A pressure differential distribution device as described in claim **20**, further comprising a protective sleeve coupled to at least a portion of said interior surface of said compressible hose.

33. A pressure differential distribution device as described in claim **31**, wherein said hose holster comprises a material selected from the group consisting of plastic, fiberglass, or metal.

34. A pressure differential distribution device as described in claim **20**, further comprising a hose entry guide coupled to said holster.

35. A pressure differential distribution device as described in claim **34**, further comprising a holster mount assembly.

36. A pressure differential distribution device as described in claim **35**, wherein said holster mount assembly is selected from the group consisting of a fixed mount, a pivot mount, and a moveable track mount.

37. A pressure differential distribution device as described in claim **20**, further comprising an emission removal adaptor.

38. A pressure differential distribution device as described in claim **37**, further comprising a emission removal adaptor restraining element.

39. A pressure differential distribution device as described in claim **38**, wherein said emission removal adaptor restraining element comprises a pair of non-scratch tabs coupled to said emission removal adaptor, and wherein said non-scratch tabs are configured to insert into a pair of substantially vertical notches and then rotate into a pair of substantially horizontal notches.

40. A pressure differential distribution device as described in claim **20**, and further comprising a spring rewind cassette.

41. A pressure differential distribution device as described in claim **20**, wherein said spring rewind cassette is motorized.

42. A pressure differential distribution device as described in claim **20**, wherein said hose retraction element comprises a pressure differential between said interior surface and said exterior surface of said compressible hose.

43. A pressure differential distribution device as described in claim **37**, wherein said emission removal adaptor has a mouth, wherein said mouth coordinates a location of a first pair of axes on a first plane of movement with a location of a second pair of axes on a second plane of movement, and wherein said first pair of axes on said first plane of movement and said second pair of axes on said second plane of movement are hingedly responsive.

44. A pressure differential distribution device as described in claim **43**, wherein said first pair of axes comprise flexible seams.

45. A pressure differential distribution device as described in claim **44**, wherein said second pair of axes comprise flexible seams.

46. A pressure differential distribution device as described in claim **44**, wherein said second pair of axes comprise a deflection apex.

47. A pressure differential distribution device as described in claim **43**, further comprising a body joined to said mouth of said emission removal adaptor.

48. A pressure differential distribution device as described in claim **47**, further comprising a tongue responsive to said body.

49. A pressure differential distribution device as described in claim **48**, further comprising a mouth closure element coupled to said mouth.

50. A pressure differential distribution device as described in claim **49**, wherein said mouth closure element is selected from the group consisting of a pair of torsion springs, a pair of band springs, a memory molded rubber, and a memory molded plastic.

51. A pressure differential distribution device as described in claim **50**, wherein said mouth closure element has mouth open memory.

52. A pressure differential distribution device as described in claim **51**, wherein said mouth closure element has mouth closed memory.

53. A pressure differential distribution device as described in claim **49**, further comprising a friction enhancement surface coupled to said mouth.

54. A pressure differential distribution device as described in claim **53**, further comprising a friction enhancement surface coupled to an interior surface of said mouth.

55. A pressure differential distribution device as described in claim **54**, wherein said friction enhancement surface comprises interdigitated teeth.

56. A pressure differential distribution device as described in claim **53**, further comprising grip knobs fixed to an exterior surface of said emission removal adaptor, wherein said grip knobs are responsive to said mouth.

57. A pressure differential distribution device as described in claim **56**, further comprising an adaptor sleeve joined between said emission removal adaptor and said compressible hose.

58. A pressure differential distribution device as described in claim **57**, wherein said repositionable closure hose retraction element comprises damper rotationally coupled to said adaptor sleeve.

59. A pressure differential distribution device as described in claim **58**, further comprising a pressure differential manifold.

60. A pressure differential distribution device as described in claim **59**, wherein said pressure differential manifold further comprises a ball socket.

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